WL-TR-94-2025

DEVELOPMENT OF A BIPOLAR LEAD/ACID BATTERY FOR THE MORE ELECTRIC AIRCRAFT

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AEROPROPULSION AND POWER DIRECTORATE
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This technical report has been reviewed and is approved for publication.

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This report summarizes the development work completed under contract F33615-91-C-2142 for the time period of September 1991 through March 1993. The focus of the work was on the development of a filled polymeric composite substrate for use in a true bipolar lead acid battery. The contract goals for the development of the substrate material are as follows:

Resistivity: $\leq$ 2 ohm-cm
Thickness: $\leq$ 0.064 cm
Weight: $\leq$ 150 mg/cm^2
Area: $\geq$ 400 cm^2

This report presents information towards achieving those goals.

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WPAFB INTERIM TECHNOLOGY REPORT
BIPOLAR BATTERY DEVELOPMENT
SEPTEMBER 1991- MARCH 1993

1. INTRODUCTION:

This report summarizes the development work completed by Johnson Controls Battery Group Inc., JCBGI, under U.S. Air Force Contract F33615-91-C-2142, Data Item #A006, for the time period of September 1991 through March 1993.

The focus of the work was on the development of a filled polymeric composite substrate for use in a true bipolar lead/acid battery. The role of the electrode in a bipolar design is paramount. The essential function of the substrate is to provide electronic conduction between the positive and negative active materials without permitting ionic conduction which would short out the cell. The substrate requirements are summarized below:

1. Electrical conductivity
2. Chemical insolubility in sulfuric acid in the potential windows of both electrodes
3. High oxygen and hydrogen overpotentials in sulfuric acid
4. Inertness to the electrode reactions
5. Ionically non-porous
6. Manufacturable

The contract goals for the development of the substrate material are found below.

Resistivity	$\leq 2\ \Omega$-cm
Thickness	0.064 cm
Weight	≤ 150 mg/cm^2
Area	≥ 400 cm^2

JCBGI has focussed its development efforts on attaining or exceeding each of these goals. The original program schedule can be found in Figure 1, and the present program schedule can be found in Figure 2.

JCBGI has extensive experience in testing and developing potential conductive fillers for bipolar lead acid batteries. To date over 100 candidates have been screened and only a few have been identified as a possible filler materials. JCBGI concentrated on developing the most promising of these fillers for use in this program. A systematic approach was used to first, prove the stability of the conductive filler, and second, develop the processing and fabrication techniques needed to produce highly conductive, thin, non-porous substrates.

The stability of the conductive filler is tested through a series of tests developed at JCBGI. The most critical of which is exposing a compounded substrate to a constant potential of 1.5 volts for a period of time varying from 4 to 34 days. This method tests both the stability of the conductive filler at positive overpotentials and the porosity of the substrate.

After improving the compounding techniques to consistently produce non-porous parts, proof of concept testing was conducted on low voltage batteries. Four volt batteries were built to prove the viability of the substrate in an actual battery and to address the next major development issue- positive active material adhesion.

The above development issues will be discussed in further detail in the upcoming sections.

2. PERFORMANCE PROJECTIONS:

A set of preliminary performance requirements for the More Electric Aircraft (MEA) energy source were given to JCBGI, by Richard Flake of WPAFB, during the program kickoff meeting on December 12, 1991. The energy source requirements are summarized below:

Main Engine Starting:	150 kW, 30 sec
Ground Power:	25-75 kW, 30-45 min
Emergency Power:	75 kW, 10 min
APU Starting:	5-10 kW, 15 sec
Hybrid Emergency:	50-75 kW, 60 sec
Temperature Range:	-65F to 120F
Voltage Window:	270 Minimum; 330 Maximum

Given the above performance requirements, JCBGI using their proprietary lead/acid battery mathematical model (LABMM), designed four different bipolar batteries for both 5- and 10- year time frames. In designing the battery system for the 5-year time frame, JCBGI assumed that the program goals for the substrate development were reached and used conventional active materials. The 10-year battery systems were modelled assuming a thinner more conductive substrate and improved active materials. The results of the modelling can be found in Figures 3 and 4. The size of the battery can change dramatically depending upon the application ranging from as small as 0.18 ft^3, 33 pounds to as large as 8.13 ft^3, 1349 pounds.

3. CONDUCTIVE FILLER DEVELOPMENT:

Building on the work performed in JCBGI's first bipolar lead/acid program with WPAFB, conductive filler development was continued in the same promising areas. Towards the end of the initial program JCBGI was having some success using one type of conductive filler that showed stability in the battery environment. Also, other conductive fillers were investigated including SiC, and Ceramic plaques and coated fibers using the same filler chemistry. JCBGI renewed working relationships with two suppliers of Conduflow, and found different companies that were interested in developing coated glass fibers with Conduflow and ceramic plaques with Conduflow.

The investigation into coated glass fibers by Photon Energy Systems was not successful. They made four different attempts on making fiber, but each of the trials could not be used because of a number of problems. First, the glass used would not withstand the acid environment. Second, the material was not uniform and was highly resistive. Third, the adhesion of the coating to the glass was virtually nonexistent which made handling next to impossible and completely eliminated any chance of compounding the material into plastic. Finally, they could only make the material on long strands of glass, 2-6", which could not be used for our application. After the fourth shipment of subpar material, which they said would be the best that they could make, activity in this area was discontinued.

After the attempt at glass fibers was not successful, the focus of development efforts was placed on Conduflow powder. Two companies were contacted and samples obtained from each. The samples were extremely similar in particle size and appearance but the material from Magnesium Elektron Inc. (MEI) was much more conductive than the Crystal Research Inc. (CRI) material. Leach tests of both materials proved that they were stable in

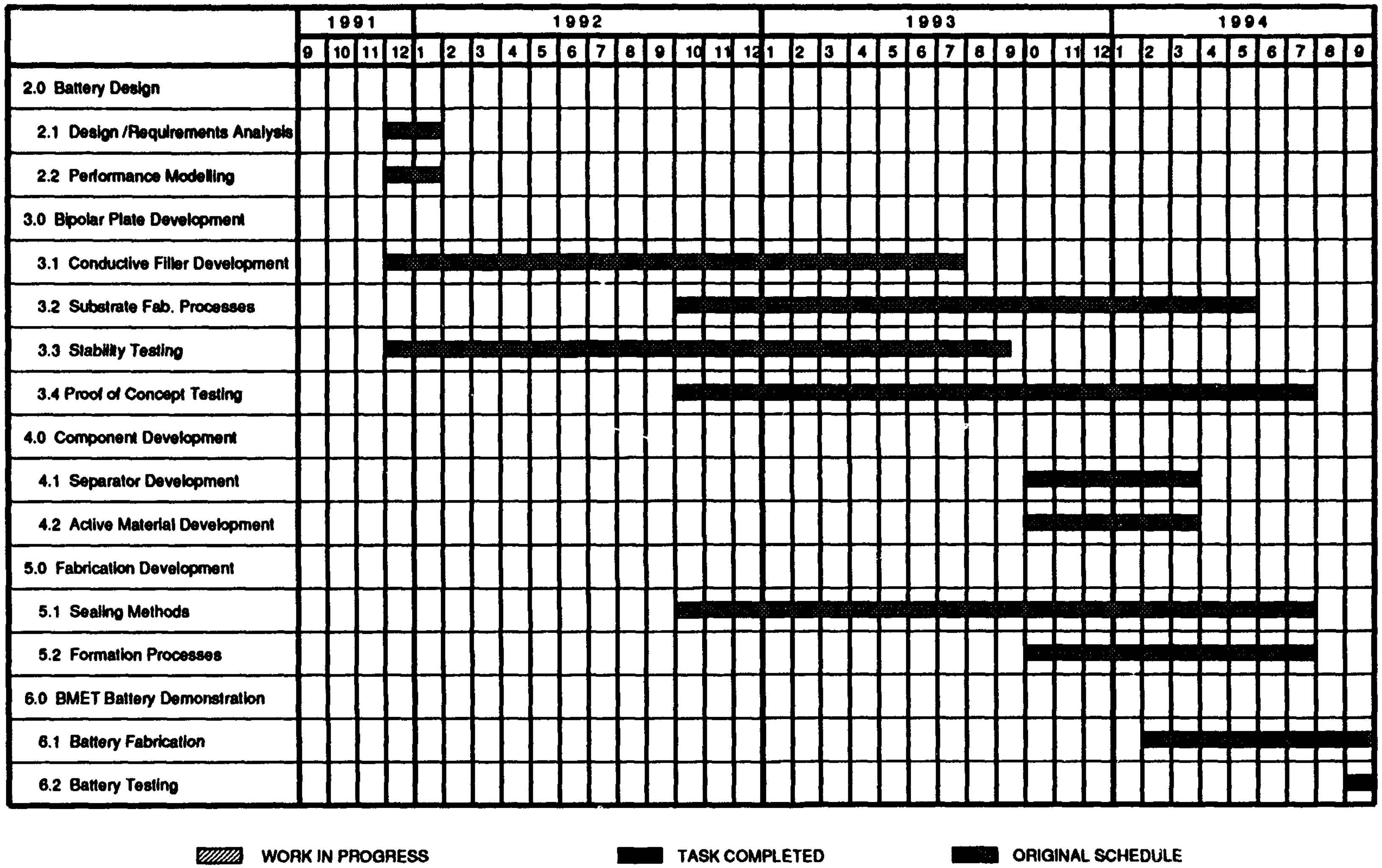

Figure 1
Original
BMET Program Schedule

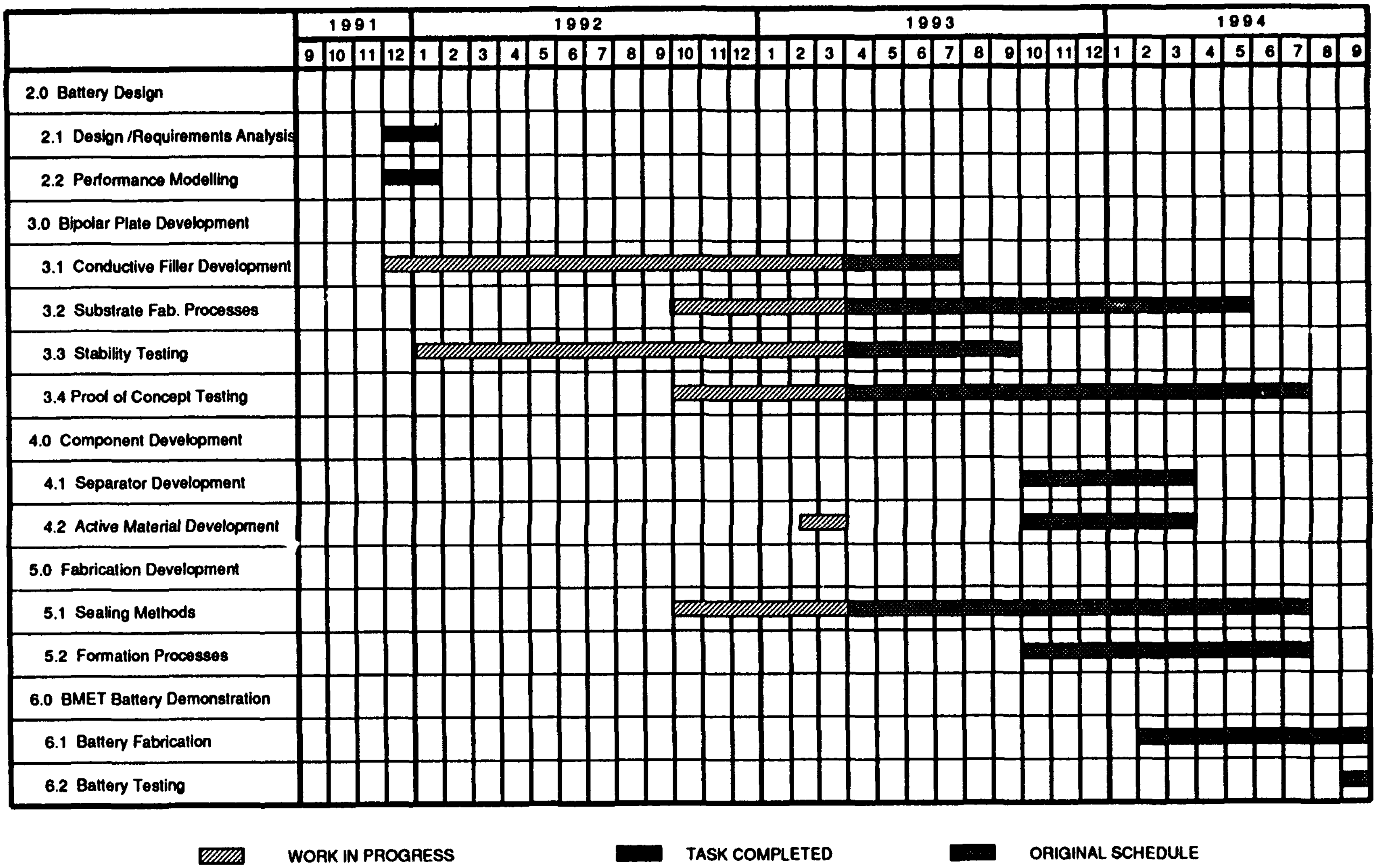

Figure 2
BMET Program Schedule

REQUIREMENTS MET	BATTERY DIMENSIONS	BATTERY VOLUME	BATTERY WEIGHT	W/kg	W/cm3	W-hr/kg	W-hr/cm3
Main Engine Starting APU Starting Hybrid Emergency	17.6"x15.5"x15.5"	2.45 ft3	450 lbs	747.9	2.2	12.25	0.036
Main Engine Starting Ground Power Emergency Power APU Starting Hybrid Emergency							
Scenario 1 30 minute ground power capacity	27.4"x19.7"x19.7"	6.15 ft3	1000 lbs	62.2	0.16	31.08	0.081
Scenario 2 45 minute ground power capacity	36.2"x19.7"x19.7"	8.13 ft3	1349 lbs	46.1	0.12	34.56	0.092
APU Starting	16.5"x4.33"x4.33"	0.18 ft3	33 lbs	705.0	2.1	11.75	0.036

Figure 3
BMET PERFORMANCE REQUIREMENTS
BIPOLAR BATTERY SPECIFICATIONS
Near Term Projections (within 5 years)
330 Volt Battery Systems

REQUIREMENTS MET	BATTERY DIMENSIONS	BATTERY VOLUME	BATTERY WEIGHT	W/kg	W/cm3	W-hr/kg	W-hr/cm3
Main Engine Starting APU Starting Hybrid Emergency	14.4"x15.5"x15.5"	2.00 ft3	389 lbs	895.3	2.8	14.17	0.044
Main Engine Starting Ground Power Emergency Power APU Starting Hybrid Emergency							
Scenario 1 30 minute ground power capacity	21.6"x19.7"x19.7"	4.85 ft3	864 lbs	72.0	0.21	35.97	0.103
Scenario 2 45 minute ground power capacity	29.9"x19.7"x19.7"	6.72 ft3	1235 lbs	50.6	0.15	37.77	0.111
APU Starting	15.2"x4.33"x4.33"	0.16 ft3	31 lbs	772.0	2.3	12.87	0.041

Figure 4
BMET PERFORMANCE REQUIREMENTS
BIPOLAR BATTERY SPECIFICATIONS
Far Term Projections (10 years)
330 Volt Battery Systems

an acid environment, but determining their stability at the positive potential of a lead acid system was more difficult. The one problem with Conduflow was that it is not stable at the negative potentials of the battery. To be able to use Conduflow as a substrate material a multi layer system would have to be used. Drawing on JCBGI's experience from the initial WPAFB contract, C-black was determined to be the ideal second half of the substrate. C-black is highly conductive, lightweight, readily available, and stable at the negative potentials. However, C-black is not stable at positive potentials, making it an ideal complement to Conduflow. During the first contract much effort was made in developing the C-black material for use as the bipolar substrate before it was proved to be unstable at positive overpotentials. Because the development work was virtually completed for the C-black substrate, efforts were concentrated on proving the stability of Conduflow. The evolution of the substrate into a two piece laminate causes the interface between the halves to become a development issue. The manufacturing developments will be discussed later.

The attempt by Materials and Electrochemical Research Inc.(MER) to produce a dense plaque of Conduflow was also not successful. The plaque was found to be dissolve and become non conductive when placed in contact with sulfuric acid. After the initial trial no further attempts were made.

At the same time that efforts were shifted towards powder Conduflow, a concurrent effort was made to develop a SiC material that could be used as a conductive filler. Qualification screening at JCBGI showed that SiC was a possible material that would be stable at both the positive and negative potentials of a battery. Samples of SiC were received from MER and found to be to resistive to use as a conductive filler. Because of this, JCBGI's efforts became even more focussed on the promising Conduflow compound.

Initial compounding trials had yielded substrates that were tested to be non-porous and stable during 4- and 5-day stability testing. Through improvements in compounding procedures, which will be discussed later, consistently stable substrates were produced. After extensive testing it was concluded that Conduflow was indeed a viable conductive filler for a bipolar lead/acid battery. Development on different fillers were discontinued to concentrate on optimizing the Conduflow and the compounding parameters needed to produce working bipolar electrodes.

The Conduflow received from MEI proved to be consistently better than any other material tested. MEI had also supplied all of the material to JCBGI, worth over $110,000, at no cost over the first 18 months of this contract. Because of the potential for this product, MEI and JCBGI entered into a joint effort for the development of Conduflow. MEI would be responsible for developing the techniques of producing and improving the material, while JCBGI would test and qualify it. MEI would also lend their compounding expertise to the development effort.

The first area to be addressed in the development of Conduflow was the particle size. It was thought that smaller particle size would eliminate the chance for porosity by being more easily wetted by the plastic resin. Initial trials using very fine particle size (< 1 micron) material yielded interesting results. The material was not as conductive as thought and also displayed more porosity than previous trials. After discussion with MEI and their compounding consultants, it was determined that the ultra fine particle size caused more problems than it solved. The small particle size lead to many more interfaces between the plastic and Conduflow which lead to higher porosity. The small particle size also caused the increase in resistance of the part. Since the conductivity of the material is dependent upon particle to particle contact, having uniform, ultra-fine particles make it more difficult to have a chain of contact throughout the thickness of the material. In fact, after further investigation the optimized particle size may be in the 10-20 micron size. Presently the particle size used is 3-5 microns, which is a result of the type of manufacturing method used. An entirely different method of production would be needed to produce material with larger particle size. After discussion with MEI, it was decided because of the timeframe of this contract, investigation into larger particle size Conduflow would not be feasible. Efforts would be better spent on optimizing the present form of Conduflow and compounding parameters.

4. FABRICATION PROCESSING TECHNIQUES:

With the focus of this contract on producing a polymer based bipolar substrate, JCBGI again moved forward from were the initial contract with WPAFB left off. Resins investigated during the first 18 months of this contract were LDPE, LLDPE, HDPE, Kynar, and PTFE. In the past all of these materials were compounded by hand in small batches using a mortar and pestle. This process was very limited in batch size and caused a large degree of variability from trial to trial. To eliminate these problems, JCBGI had proposed to use contract funding to purchase a Brabender type of mechanical mixer. Prior to beginning the contract, another group in JCI had purchased a similar machine. Because of the high loading levels needed (75-85% by weight) to make the material conductive enough, special equipment is needed to compound the material. The Brabender mixer was proposed to do this compounding. However, initial trials with the mixer showed that it would not work on loading levels higher than 70%. Because of this, the Brabender mixer was never purchased and JCBGI began looking for different methods to compound the material. It was recommended to JCBGI that the best equipment for JCBGI to use would be a twin screw extruder.

Prior to purchasing a twin screw extruder, JCBGI had material compounded by two different vendors using similar equipment to verify that it would work at the loading levels needed. Two trails were run by Dr. John Muzzy, of Georgia Tech University, and MEI to determine if a twin screw extruder would work for our application. The success of the trials convinced JCBGI to purchase an extruder instead of the Brabender mixer. The unit was ordered in December of 1991, and was ready to run at JCBGI in late March of 1993.

It was thought at the beginning of the contract that the cause of the porosity problems in the substrates was caused by trapped gases during compression molding of the material into sheets. To eliminate the trapped gas, JCBGI and a local vendor, Molded Rubber and Plastics, designed a vacuum compression mold. In theory, by compression molding under a vacuum, any trapped gas in the material would be removed and result in a porous free part. After many different trials, stability testing showed that the parts made with the vacuum mold were not any better than parts in the conventional manner. Because of the cost of the process, \$65-\$75 per 12" x 12" part, and the large amount of material needed per trial, 10+ pounds, work in this area was discontinued.

Because of the success late in the initial program using LDPE as the base resin, JCBGI began its development using the same resin. The plastic, called Microthene, is purchased from Quantum Chemical Corp. in powder form. Using a powder form of the plastic results in a much more uniform dispersion of the filler material and helps eliminate porosity. The conductive filler and the plastic are dry mixed prior to melt blending. The material is then compression molded, laminated to the C-black material, and cut to size for testing.

JCBGI's approach in developing processing parameters for a this contract were using one resin, LDPE, to first prove the stability of the conductive filler, second to optimize part conductivity and eliminate part porosity, and third to reduce part thickness from around 0.070" to the contract goal of 0.025". To prove the stability of the filler, test parts were hand compounded at lower loading levels 80-82.5% by weight, and compression molded to a thickness of 0.070" and stability tested. After a series of successful tests, no change in resistivity after 4-34 days while maintaining a positive potential of 1.5 volts, the emphasis changed towards making the parts thinner, and more conductive.

Because the properties of the filler dictate a loading level of 80-85% by weight is needed to produce part conductivity high enough for use in a battery, JCBGI began investigating additives that would improve the physical properties of the substrate. MEI has extensive experience with producing conductive materials and suggested the following additives which could improve part conductivity, reduce porosity, and/or improve manufacturing- coupling agents, paraffin oil, stearic acid, ethylene vinyl acetate, and fumed silica. After investigating all of these additives it was found that only coupling agents offered the only real advantage. The others while improving part conductivity caused additional problems with part porosity.

Since initial efforts with coupling agents were so promising, a series of trials were conducted to optimize the loading level and addition method of the material. Two different coupling agents were attempted per the advice of Kenrich Chemical Inc.. Of the two materials, one was clearly better at all loading levels. The coupling agents are used in small quantities, 0.01-1.00% by weight, of the filler. They are designed to bond between the filler and the base resin. The particular material used, LICA 38, is fumed silica which has been treated with the coupling agent. The coupling agent improved part conductivity and reduced part porosity at levels between 0.35%-1.00%. At levels higher than 1.00%, the additional material did not offer any improvement over the 1.00% level. It was also found that the order of addition was critical to the performance of the material. It was much more effective to blend the coupling agent with the conductive filler prior to adding the resin.

All of the development work was done using the powder form of the LDPE. This material had given JCBGI the best results to date. At the same time, other base resins were evaluated but none were found to have all the manufacturing advantages of LDPE. Recently, JCBGI has also been investigating HDPE which would give the substrate more high temperatures capabilities and a more rigid structure. Depending upon the application, the resin with the best properties can be used.

JCBGI also looked at using PTFE as a base resin. When loaded at 70-75%, the material was highly conductive, 1 Ω-cm, but was also highly porous. To combat the porosity, resin impregnation was attempted. The material was treated by Imprex Inc., with a polycarbonate based liquid resin under a vacuum. It was thought that the resin impregnation would remove the porosity while not hindering the conductivity. It did neither. The parts remained porous and became more resistive after the resin treatment. The activity as well as PTFE development was stopped.

Another resin investigated was Kynar. The material showed initial promise during hand compounding trials as producing conductive and non-porous material. However, the high temperatures needed to mold and compound material (375C) caused problems with the Conduflow. JCBGI attempted to use blends of LDPE and Kynar which resulted in conductive but highly porous material. Because of the problems with Kynar and the promise of LDPE, development in this area was discontinued.

The development efforts for the C-black part of the substrate were much easier because of the vast experience JCBGI has using C-black for the Zn/Br_2 battery development program. JCBGI had screened several different types of C-black before choosing a Ketjenblack material, EC600JD, from Azko Chemical. After several iterations, the loading level of C-black in the LDPE was found to be 19% by weight. This afforded parts with conductivity of 1-1.6 Ω-cm and enough flexibility to be used as a bipolar substrate.

The fact that Conduflow is not stable at negative potentials meant that a laminate system would have to be used to protect it. This lead to development of the interface between the Conduflow substrate and the C-black substrate. Initial trials of compression molding the two halves together resulted in a part with higher resistivity than than the sum of the pieces. This was caused by the "skins" which are formed on the surfaces of each of the flat sheets during compression molding. Two different methods were attempted to remove the effect of laminating the "skins" together. The first was to add C-black to the interface prior to compression molding the two pieces together. This proved to be effective but was rather difficult to apply a uniform coating of the C-black to the interface. The second method attempted was to remove the skins on the interface by using sand paper. This worked better than the C-black addition and was much easier to use. Sanding the faces of the sheet stock prior to lamination resulted in a 50-75% reduction in part resistivity and no effect on part stability.

5. STABILITY TESTING:

A diagram of the stability test fixture can be found in Figure 5. A summary of all stability tests run can be found in Figure 6. Figure 7 is a graph of a typical stability test.

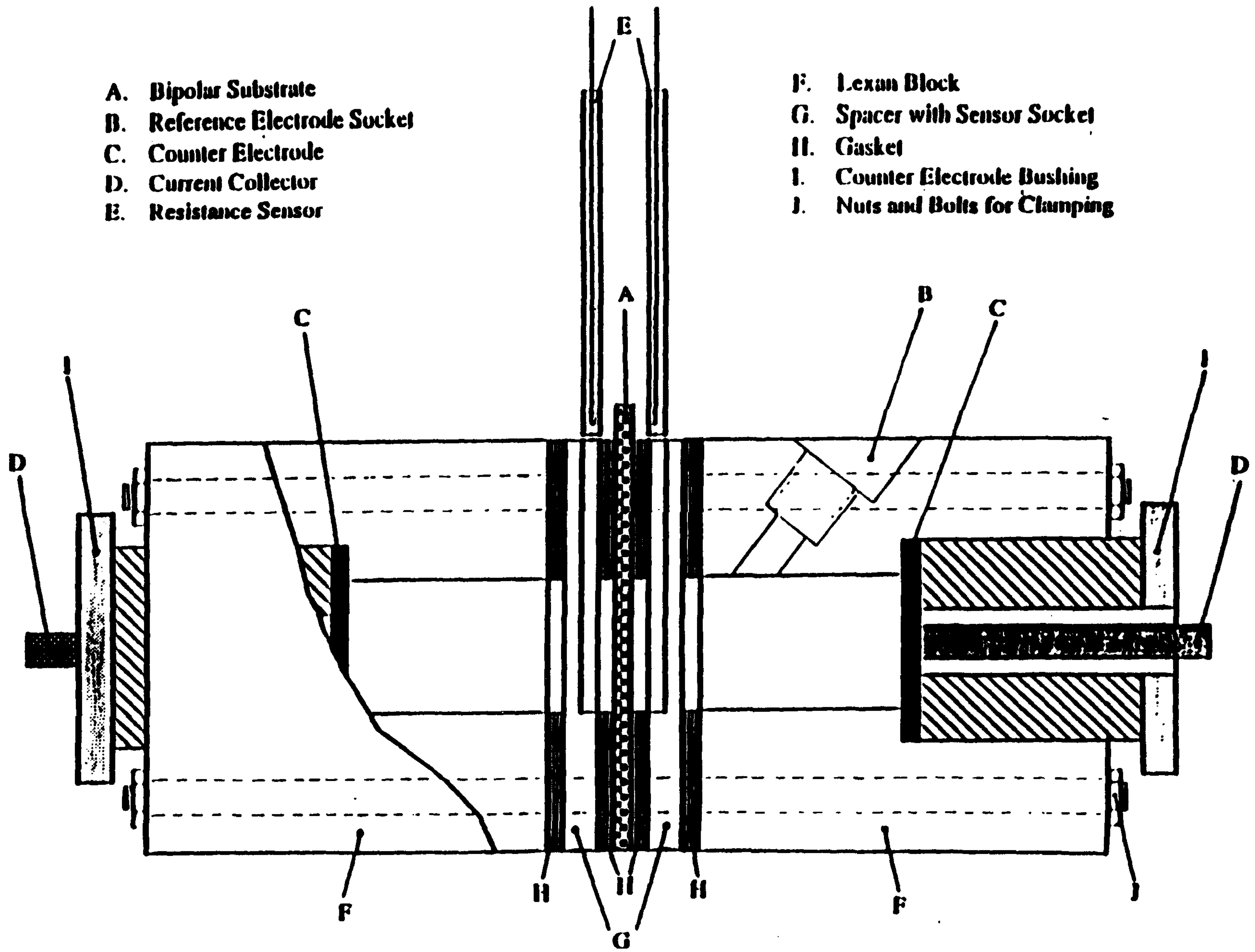

Figure 5 Stability Test Fixture

REVISED- 21-OCT-1992 STABILITY TESTING

SAMPLE NO.	DATE	MATERIAL COMPOSITION	RESISTANCE (OHM) BEFORE	THICKNESS (INCH) BEFORE	RESISTIVITY (OHM-CM) BEFORE	RESISTANCE (OHM) AFTER	THICKNESS (INCH) AFTER	RESISTIVITY (OHM-CM) AFTER	PERCENT CHANGE (%)
47A	4/2/92	LAMINATED 85% GC23N	0.365	0.023	6.248	0.960	0.042	8.999	
	RMH LAB BOOK	W/O CAPOW L/12H	0.450	0.024	7.382	0.640	0.042	5.999	
	PG.103	15% MICROTHENE	0.270	0.023	4.622	1.060	0.042	9.936	
		4.5 M.I.			6.084			8.311	36.616
		C-PLASTIC							
48A	4/2/92	LAMINATED 85% GC23N	0.630	0.025	9.921	1.000	0.040	9.843	
	RMH LAB BOOK	WITH CAPOW L/12H	0.570	0.024	9.350	1.500	0.040	14.764	
	PG.103	15% MICROTHENE	0.635	0.024	10.417	0.740	0.040	7.283	
		4.5 M.I.			9.896			10.630	7.415
		C-PLASTIC							
52	4/9/92	LAMINATED 84% GC23N	1.180	0.053	8.765	19.500	0.062	123.825	
	RMH LAB BOOK	& 16%PTFE DUPONT TO				17.500	0.062	111.125	
	PG.107	C-PLASTIC & pb FOIL				38.000	0.063	237.470	
		SINGLE APPLICATION						157.474	1696.534
		OF RESIN							
53	4/9/92	LAMINATED 84% GC23N	3.630	0.061	23.428	169.000	0.054	1232.138	
	RMH LAB BOOK	& 16%PTFE DUPONT TO				161.000	0.054	1173.812	
	PG.107	C-PLASTIC & pb FOIL				188.000	0.054	1370.662	
		DOUBLE APPLICATION						1258.870	5273.261
		OF RESIN							
54B	4/14/92	LAMINBATED 85% GC23N	0.195	0.040	1.919	0.440	0.040	4.331	
	RMH LAB BOOK	15% MICROTHENE				0.483	0.040	4.754	
	PG.113	1.5 M.I.				0.470	0.040	4.626	
		WITH pb FOIL						4.570	138.120
55B	4/14/92	LAMINATED 85% GC23N-	0.250	0.030	3.281	1.730	0.030	22.703	
	RMH LAB BOOK	15% MICROTHENE				2.350	0.030	30.840	
	PG.113	1.5 M.I.				3.600	0.030	47.244	
		W/O pb FOIL						33.596	924.000
71A	4/24/92	LAMINATED	0.295	0.206	0.564	0.390	0.209	0.735	
	RMH LAB BOOK	THICK/THICK	0.300	0.208	0.568	0.430	0.211	0.802	
	PG. 120	GC23N-1 /C-PLASTIC	0.280	0.208	0.530	0.400	0.208	0.757	
					0.554			0.765	38.065
72A	4/24/92	LAMINATED	0.275	0.208	0.521	0.495	0.210	0.928	
	RMH LAB BOOK	THIN/THIN	0.265	0.208	0.502	0.410	0.210	0.769	
	PG. 120	GC23N-2 /C-PLASTIC	0.275	0.207	0.523	0.500	0.209	0.942	
					0.515			0.880	70.763
73A	4/24/92	LAMINATED	0.420	0.031	5.334	3.800	0.031	48.260	
	RMH LAB BOOK	THICK/THIN	0.250	0.032	3.076	8.800	0.031	111.760	
	PG. 120	GC23N-3 /C-PLASTIC	0.220	0.033	2.625	6.400	0.032	78.740	
					3.678			79.587	2063.769
74A	4/24/92	LAMINATED	0.380	0.032	4.675	4.300	0.032	52.904	
	RMH LAB BOOK	THIN/THIN	0.440	0.033	5.249	5.100	0.033	60.845	
	PG. 120	GC23N-4 /C-PLASTIC	0.430	0.031	5.461	5.500	0.032	67.667	
					[illegible]			60.472	1079.129

STABILITY TESTING

SAMPLE NO.	DATE	MATERIAL COMPOSITION	RESISTANCE (OHM) BEFORE	THICKNESS (INCH) BEFORE	RESISTIVITY (OHM-CM) BEFORE	RESISTANCE (OHM) AFTER	THICKNESS (INCH) AFTER	RESISTIVITY (OHM-CM) AFTER	PERCENT CHANGE (%)
75A	4/24/92	LAMINATED	0.350	0.121	1.139	0.570	0.122	1.839	
	RMH LAB BOOK	THICK/THIN	0.580	0.122	1.872	0.520	0.123	1.664	
	PG. 120	GC23N-5 /C-PLASTIC	0.280	0.123	0.896	0.320	0.123	1.024	
					1.302			1.509	15.906
76A	4/24/92	LAMINATED	0.285	0.124	0.905	2.350	0.125	7.402	
	RMH LAB BOOK	THIN/THICK	0.275	0.126	0.859	2.580	0.124	8.192	
	PG. 120	GC23N-6 /C-PLASTIC	0.270	0.126	0.844	2.300	0.123	7.362	
					0.869			7.652	780.247
77A	5/12/92	LAMINATED							
	RMH LAB BOOK	GC23N-A-3/92							
	Pg.130	Pb-FOIL							
		C-PLASTIC	0.360	0.026	5.451				
		LAMINATED							
		GC23N-B-3/92							
		Pb-FOIL							
		C-PLASTIC	0.220	0.026	3.331				
		LAMINATED							
		GC23N-B-3/92							
		Pb-FOIL							
		C-PLASTIC	0.660	0.027	9.624				
78A	6/5/92	LAMINATED							
	RMH LAB BOOK	GC23N, MICROTHENE &							
	Pg.131	C-PLASTIC							
	POROSITY TEST	1R	0.228	0.030	2.992	0.380	0.030	4.987	66.667
	AFTER	2R	0.185	0.030	2.428	5.800	0.030	76.115	3035.135
	RESIN TREATMENT	3R	0.210	0.027	3.062	0.660	0.028	9.280	203.061
	3/92 [redacted]								
	TESTING ON 2 & 3								
	INTERRUPTED								
	AFTER 3 POINT								
79A	5/20/92	LAMINATE							
	RMH LAB BOOK	GC23N-1-85%	0.520	0.046	4.451	3.700	0.046	31.667	611.538
	Pg.137	MICROTHENE/CAPOW							
	FOR ACID	GC23N-2-85%	0.335	0.044	2.997	2.200	0.044	19.685	556.716
	ABSORBTION TEST	MICROTHENE							
	ON 3/92 [redacted]	GC23N-3-80.3%	0.490	0.039	4.946	21.000	0.041	201.652	3976.655
		KYNAR							
		GC23N-4-80.3%	0.435	0.037	4.629	13.500	0.038	139.867	2921.779
		KYNAR/CAPOW							
80A	5/27/92	LAMINATE							
	RMH LAB BOOK	GC23N-1-85%	0.360	0.040	3.543	0.445	0.040	4.380	23.611
	Pg.139/141	MICROTHENE/CAPOW							
	REMAKE OF TEST	GC23N-2-85%	0.495	0.039	4.997	0.525	0.038	5.439	8.852
	79A USING	MICROTHENE							
	5/92-[redacted]	GC23N-3-80.3%	0.223	0.044	1.995	0.253	0.044	2.264	13.453
		KYNAR							
		GC23N-4-80.3%	0.305	0.042	2.859	0.350	0.041	3.361	17.553

REVISED- 21-OCT-1992 STABILITY TESTING

SAMPLE NO.	DATE	MATERIAL COMPOSITION	RESISTANCE (OHM) BEFORE	THICKNESS (INCH) BEFORE	RESISTIVITY (OHM-CM) BEFORE	RESISTANCE (OHM) AFTER	THICKNESS (INCH) AFTER	RESISTIVITY (OHM-CM) AFTER	PERCENT CHANGE (%)
		KYNAR/CAPOW							
81A	6/9/92	LAMINATED							
	RMH Lab Book	GC23N,MICROTHENE &							
	Pg.145	C-PLASTIC							
	Remake of test	5/92-1R							
	78	5/92-2R							
	Using 5/92 [redacted]	5/92-3R							
		5/92-4R							
82A	6/10/92	laminated							
	RMH Lab Book	[redacted]							
	Pg.147	and C-Plastic	0.380	0.098	1.527	23.300	0.098	93.604	6031.579
	Tested sample								
	from [redacted] Corp.								
84A	6/26/92	laminated							
	RMH Lab Book	[redacted]							
	Pg.151	Kynar 7201 & 711							
	Kynar-2 types	C-Plastic							
	7201 & 711	Capow							
		70%-7201	1.700	0.031	21.590	26.300	0.031	334.011	1447.050
		75%-7201	0.540	0.031	6.850	220.000	0.033	2624.672	38171.605
		85%-711	0.450	0.059	3.003				
		70%-7201 & Capow	0.785	0.032	9.658	1.750	0.031	22.225	130.121
		75%-7201 & Capow	0.680	0.033	8.113	6.400	0.032	78.740	870.508
		85%-711 & Capow	0.320	0.062	2.032				
85A	6/30/92	LAMINATES							
	R.M.H. lab book	[redacted]							
	pg.154	C-Plastic , Pb Foil							
		711 Kynar & Pb Dust							
		70%-W/CA-FOIL	3.700	0.022	66.213				
		70%-W/CA-DUST	0.600	0.022	10.737				
		70%-W/O CA-FOIL	2.150	0.022	38.475				
		70%-W/O CA-DUST	0.320	0.025	5.039	71.500	0.025	1125.984	22243.750
		75%-W/CA-FOIL	0.097	0.024	1.591	12.000	0.025	188.976	11776.289
		75%-W/CA-DUST	0.430	0.024	7.054	73.000	0.026	1105.391	15570.841
		75%-W/O CA-FOIL	1.250	0.025	19.685				
		75%-W/O CA-DUST	0.300	0.026	4.543	70.000	0.028	984.252	21566.667
88A	7/13/92	5/92-[redacted]							
	R.M.H.lab book	Kynar-711							
	pg.159/160	C-Plastic							
		.013-C-Plastic	0.110	0.013	3.331	0.115	0.012	3.773	13.258
	The sample .050	.020-[redacted]	0.650	0.033	7.755				
	[redacted] was	.030-[redacted]	1.150	0.042	10.780	3.850	0.042	36.089	234.783
	repressed at 540 F	.040 [redacted]	1.550	0.050	12.205	1.130	0.048	9.268	-24.059
	for better	.050-[redacted]	1.650	0.054	12.030	1.680	0.054	12.248	1.818
	resistivity								
92A	7/22/92	LEAD DUST &	0.043	0.028	0.605				
	R.M.H.lab book	RADEL(POLYSULFONE)							
	pg.167	PREMIXED W/1.1.1							
		DRIED PRESSED AT							

REVISED- 21-OCT-1992 STABILITY TESTING

SAMPLE NO.	DATE	MATERIAL COMPOSITION	RESISTANCE (OHM) BEFORE	THICKNESS (INCH) BEFORE	RESISTIVITY (OHM-CM) BEFORE	RESISTANCE (OHM) AFTER	THICKNESS (INCH) AFTER	RESISTIVITY (OHM-CM) AFTER	PERCENT CHANGE (%)
		599£ 30 TONS							
		55% BY WT.							
94A	7/28/92	LAMINATE							
	R.M.H.lab book	[redacted]							
	pg.170/171	KYNAR-711							
		&							
		KETJENBLACK WITH							
		KYNAR-711							
		14%-KET/KYN-.050	0.305	0.068	1.766	0.480	0.068	2.779	57.377
		14%-KET/KYN-.040	0.380	0.061	2.453	0.400	0.061	2.582	5.263
		14%-KET/KYN-.030	0.500	0.051	3.060	0.740	0.051	5.713	48.000
		pb/RADEL	0.066	0.025	1.039	0.570	0.025	8.976	763.636
95A	7/30/92	LAMINATE							
	R.M.H.lab book	[redacted]							
	pg.173/174	KYNAR-7201							
		&							
		KETJENBLACK WITH							
		KYNAR-7201							
		14%-KET/KYN-.050	0.305	0.066	1.819	0.345	0.066	2.058	13.115
		14%-KET/KYN-.040	0.295	0.061	1.904	0.400	0.061	2.582	35.593
		14%-KET/KYN-.030	0.270	0.052	2.044	1.150	0.052	8.707	325.926
		14%-KET/KYN-.020	0.255	0.043	2.335	4.200	0.043	38.454	1547.059
		14%-KET, KYN-.026	0.243	0.047	2.036	SAMPLE	FOR	SHOW	
96A	8/10/92	LAMINATES							
	R.M.H. lab book	[redacted] W/Microthene							
	pg.175/178	Ketjenblack &							
		Microthene							
	325£/3000#	80%-[redacted]-96A-1	0.620	0.071	3.438	0.640	0.071	3.549	3.226
	used to make	80%-[redacted]-96A-2	0.460	0.063	2.875	0.440	0.063	2.750	-4.348
	laminates								
97A	8/18/92	LAMINATES							
	RMH lab book	[redacted] Kynar(8/92)							
	pg.181	Ket/Kynar(8/92)							
	400£/3000#	75%-[redacted]-97A-1	0.210	0.052	1.590	1.650	0.052	12.492	685.714
	used to make	75%-[redacted]-97A-2	0.230	0.063	1.437	0.430	0.063	2.687	86.957
	laminates	75%-[redacted]-97A-3	0.218	0.067	1.281	0.290	0.067	1.704	33.028
99A	8/21/92	LAMINATES							
	RMH lab book	[redacted] Kynar							
	pg.185/186	Ket/Kynar							
	400£/3000#	75%-[redacted]-99A-1	0.250	0.074	1.330	0.310	0.074	1.649	24.000
	used to make	75%-[redacted]-99A-2	0.220	0.076	1.140	0.320	0.076	1.658	45.455
	laminates	75%-[redacted]-99A-3	0.225	0.060	1.476	0.510	0.060	3.346	126.667
		75%-[redacted]-99A-4	0.185	0.060	1.214	0.330	0.060	2.165	78.378
102A	9/16/92	LAMINATES							
	RMH lab book	[redacted] MICROTHENE							
	pg.189	KET/MICROTHENE							
	350£/3000#	80%-[redacted]-102A-1	1.550	0.061	10.004	2.400	0.062	15.240	52.341
	used to make	80%-[redacted]-102A-2	1.150	0.073	6.202	1.630	0.077	8.334	34.376
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

REVISED- 21-DEC-1992

STABILITY TESTING

SAMPLE NO.	DATE	MATERIAL COMPOSITION	RESISTANCE (OHM) BEFORE	THICKNESS (INCH) BEFORE	RESISTIVITY (OHM-CM) BEFORE	RESISTANCE (OHM) AFTER	THICKNESS (INCH) AFTER	RESISTIVITY (OHM-CM) AFTER	PERCENT CHANGE (%)
	material from ALCAN CHEM.LTD.	80%[redacted]-102A-4	1.130	0.046	9.671	1.830	0.048	15.010	55.199
103A	9/23/92	laminates							
	RMH lab book	WASHED [redacted]							
	pg.191	PRECOMPOUNDED							
	350£/3TONS	C-PLASTIC							
	used to make	103A-1	0.580	0.080	2.854	1.500	0.080	7.382	158.621
	laminates	103A-2	0.595	0.063	3.718	6.000	0.063	37.495	908.403
		103A-3	0.375	0.050	2.953	2.800	0.050	22.047	646.667
		103A-4	0.355	0.040	3.494	12.500	0.040	123.031	3421.127
104A	9/29/92	laminates							
	RMH lab book	WASHED [redacted]							
	pg.193	(H2O , H2SO4)							
	350£/3TONS	PRECOMPOUNDED							
	used to make	C-PLASTIC							
	laminates	104A-1	0.330	0.047	2.764	8.500	0.047	71.201	2475.758
		104A-2	0.440	0.058	2.987	3.200	0.058	21.721	627.273
		104A-3	0.310	0.064	1.907	5.200	0.064	31.988	1577.419
		104A-4	0.355	0.073	1.915	2.900	0.073	15.640	716.901
		104A-5	0.720	0.048	5.906	10.300	0.048	84.482	1330.556
		104A-6	0.700	0.062	4.445	5.500	0.062	34.925	685.714
		104A-7	0.455	0.066	2.714	5.500	0.066	32.808	1108.791
		104A-8	0.540	0.066	3.221	4.300	0.066	25.650	696.296
105A	10/9/92	KYNAR (7/92) &							
	RMH lab book	MICROTHENE (5/92)							
	pg.199	80%-LOADING							
	350£/3TONS	[redacted] (5/92)							
	used to make	10%KY/90%MIC.-105A-1	0.170	0.056	1.195	0.450	0.056	3.164	164.706
	laminates	20%KY/80%MIC.-105A-2	0.185	0.053	1.374	0.780	0.053	5.794	321.622
		30%KY/70%MIC.-105A-3	0.173	0.053	1.285	1.850	0.053	13.742	969.364
		40%KY/60%MIC.-105A-4	0.165	0.050	1.299	2.800	0.050	22.047	1596.970
109A		KYNAR (7/92) &							
		MICROTHENE (5/92)							
		80%-LOADING							
		[redacted] (5/92)							
		109A-1	0.290	0.041	2.785				
		109A-2	0.360	0.040	3.543	0.870	0.040	8.563	141.667
		109A-3	0.330	0.041	3.169	44.000	0.042	412.448	12915.873
		109A-4	0.440	0.039	4.442	0.850	0.041	8.162	83.758
110A	10-26-92	LAMINATES							
		80% [redacted](5/92)							
		MICRO.(5/92) &							
		KYNAR(7/92)							
	400F/3 TONS	110A-1	0.225	0.038	2.331	4.900	0.038	50.767	2077.778
	400F/3 TONS	110A-2	0.350	0.039	3.533	4.800	0.039	48.455	1271.429
	400F/3 TONS	110A-3	0.220	0.042	2.062	1.750	0.042	16.404	695.455
	400F/3 TONS	110A-4	0.330	0.041	3.169	0.570	0.041	5.473	72.727
111A	10/29/92	LAMINATES							

REVISED- 21-DEC-1992

STABILITY TESTING

SAMPLE NO.	DATE	MATERIAL COMPOSITION	RESISTANCE (OHM) BEFORE	THICKNESS (INCH) BEFORE	RESISTIVITY (OHM-CM) BEFORE	RESISTANCE (OHM) AFTER	THICKNESS (INCH) AFTER	RESISTIVITY (OHM-CM) AFTER	PERCENT CHANGE (%)
		MICRO.[redacted]							
	350F/3 TONS	85%-LOADING							
		111A-1	1.000	0.042	9.374	1.950	0.042	18.279	95.000
	350F/3 TONS	80%-LOADING							
		111A-2	2.100	0.043	19.227	3.000	0.043	27.467	42.857
		KYNAR[redacted]							
	400F/3 TONS	75%-LOADING							
		111A-3	0.800	0.053	5.943	1.200	0.053	8.914	50.000
		MICRO.[redacted]							
	350F/3 TONS	80%-LOADING							
		111A-4	1.800	0.036	19.685	2.000	0.036	21.872	11.111
112A	11/5/92	LAMINATES							
		75% LOADING							
		H20 WASHED							
		[redacted](7/92)							
		KYNAR(7/92)							
		14%KETJENBLACK(9/92)							
		KYNAR(7/92)							
	400F/3 TONS	112A-1	0.150	0.089	0.664		0.089	0.000	-100.000
	400F/3 TONS	112A-2	0.165	0.088	0.738		0.088	0.000	-100.000
		LAMINATES							
		80% LOADING							
		H20 WASHED							
		[redacted](7/92)							
		MICROTHENE(5/92)							
		PRECOMPOUNDED							
		C-PLASTIC							
	325F/3 TONS	112A-3	0.460	0.069	2.625		0.069	0.000	-100.000
	325F/3 TONS	112A-4	0.580	0.075	3.045		0.075	0.000	-100.000
113A	11/10/92	LAMINATES							
		H20 WASHED							
		80% [redacted](7/92)							
		MICROTHENE(5/92)							
		CAPOW L38/H							
		PRECOMPOUNDED							
		C-PLASTIC							
	325F/3 TONS	113A-1	0.490	0.064	3.014	4.700	0.064	28.912	859.184
	325F/3 TONS	113A-2	0.370	0.066	2.207	4.600	0.066	27.440	1143.243
	325F/3 TONS	113A-3	0.360	0.074	1.915	0.850	0.074	4.522	136.111
	325F/3 TONS	113A-4	0.410	0.068	2.374	0.710	0.068	4.111	73.171
114A	11/10/92	LAMINATES							
	SAME AS 113A	H20 WASHED							
	EXCEPT CAPOW MIXED	80% [redacted](7/92)							
	INTO [redacted]	MICROTHENE(5/92)							
		CAPOW L38/H							
		PRECOMPOUNDED							
		C-PLASTIC							
	325F/3 TONS	114A-1	0.430	0.062	2.731	1.750	0.062	11.113	306.977
	325F/3 TONS	114A-2	0.420	0.069	2.396	1.360	0.069	7.760	223.810
	325F/3 TONS	114A-3	0.460	0.068	2.663	0.970	0.068	5.616	110.870
	325F/3 TONS	114A-4	0.640	0.076	3.315	1.050	0.076	5.439	64.063

REVISED- 21-DEC-1992

STABILITY TESTING

SAMPLE NO.	DATE	MATERIAL COMPOSITION	RESISTANCE (OHM) BEFORE	THICKNESS (INCH) BEFORE	RESISTIVITY (OHM-CM) BEFORE	RESISTANCE (OHM) AFTER	THICKNESS (INCH) AFTER	RESISTIVITY (OHM-CM) AFTER	PERCENT CHANGE (%)
115A	11/24/92	LAMINATES							
		80% LOADING [redacted]							
NO HEAT		(7/92) H2O WASHED							
FIRST WASH		20% MICROTHENE							
THEN FILTERED		DIFFERENT H20							
		WASHING TECH.							
		PRECOMPOUNDED							
		C-PLASTIC							
		.2%/.07GMS CAPOW							
		L38/H							
		325F/3 TONS							
	325F/3 TONS	115A-1 COARSE-X	0.380	0.073	2.049	0.520	0.072	2.843	38.743
	325F/3 TONS	115A-2 COARSE-X	0.350	0.072	1.914	0.520	0.072	2.843	48.571
	325F/3 TONS	115A-3 MEDIUM-X	0.460	0.062	2.921	0.960	0.062	6.096	108.696
	325F/3 TONS	115A-4 MEDIUM-X	0.580	0.067	3.400	1.180	0.067	6.934	103.440
116A	11/25/92	LAMINATES							
		80% LOADING [redacted]							
HEAT - ALL		(7/92) H20 WASHED							
THREE WASHES		20% MICROTHENE							
THEN FILTERED		DIFFERENT H20							
		WASHING TECH.							
		PRECOMPOUNDED							
		C-PLASTIC							
		.2%/.07GMS CAPOW							
		L38/H							
		325F/3 TONS							
	325F/3 TONS	116A-1 COARSE	0.370	0.077	1.892				
	325F/3 TONS	116A-2 COARSE	0.300	0.071	1.664				
	325F/3 TONS	116A-3 MEDIUM	0.880	0.067	5.171				
	325F/3 TONS	116A-4 MEDIUM	0.610	0.066	3.639				
117A	12/03/92	LAMINATES							
		80% LOADING [redacted]							
	CAPOW/MICROTHENE	(7/92) H20 WASHED							
	MIXED FIRST	20% MICROTHENE							
	THEN INTO [redacted]	PRECOMPOUNDED							
		C-PLASTIC							
		.15% TO .45% CAPOW							
		L38/H							
		325F/3 TONS							
		117-1A (.15%)	0.380	0.071	2.107	0.980	0.071	5.434	157.895
		117-2A (.20%)	0.510	0.071	2.028	1.150	0.071	6.377	125.490
		117-3A (.25%)	0.420	0.068	2.432	0.700	0.066	4.176	71.717
		117-4A (.30%)	0.560	0.068	3.242	0.980	0.068	5.674	75.000
		117-5A (.35%)	0.420	0.071	2.329				
		117-6A (.40%)	0.460	0.065	2.786				
		117-7A (.45%)	0.640	0.064	3.937				
118A	12/07/92	LAMINATES							
	CAPOW/SNO2	80% LOADING [redacted]							
	MIXED FIRST	(7/92) H20 WASHED							
	THEN MICROTHENE	20% MICROTHENE							
		PRECOMPOUNDED							

REVISED- 04-JAN-1993

STABILITY TESTING

SAMPLE NO.	DATE	MATERIAL COMPOSITION	RESISTANCE (OHM) BEFORE	THICKNESS (INCH) BEFORE	RESISTIVITY (OHM-CM) BEFORE	RESISTANCE (OHM) AFTER	THICKNESS (INCH) AFTER	RESISTIVITY (OHM-CM) AFTER	PERCENT CHANGE (%)
	118	C-PLASTIC							
		.15% TO .45% CAPOW							
		L38/H							
		325F/3 TONS							
		118-1A (.15%)	0.400	0.068	2.316				
		118-2A (.20%)	0.400	0.071	2.218				
		118-3A (.25%)	0.380	0.068	2.200				
		118-4A (.30%)	0.330	0.068	1.911	0.400	0.069	2.282	19.455
		118-5A (.35%)	0.300	0.068	1.737	0.400	0.067	2.350	35.323
		118-6A (.40%)	0.400	0.069	2.282	0.460	0.069	2.625	15.000
		118-7A (.45%)	0.360	0.068	2.084	0.450	0.068	2.605	25.000
119A	12/04/92	THIN LAMINATES							
	119A	80% LOADING [redacted]							
COARSE [redacted]		(7/92) H2O WASHED							
USED IN 116		20% MICROTHENE							
		PRECOMPOUNDED							
		C-PLASTIC							
		.25% CAPOW L38/H							
		325F/3 TONS							
		119-1A	0.500	0.038	5.180				
		119-2A	0.340	0.038	3.523				
		119-3A	0.225	0.033	2.684				
		119-4A	0.420	0.030	5.512				
	120A								
120A	12/16/92	HAND COMPOUNDED							
	85% LOADING [redacted]	CARBON PLASTIC							
	PRECOMPOUNDED	120-1A 350F	0.430	0.058	2.919				
	WITH MICROTHENE	120-2A 350F	0.510	0.061	3.292				
		120-3A 375F	0.380	0.059	2.536				
	HAND COMPOUNDED	120-4A 375F	0.440	0.062	2.794				
	CARBON PLASTIC VS	PRECOMPOUNDED							
	PRECOMPOUNDED	CARBON PLASTIC							
	CARBON PLASTIC	120-5A	1.300	0.056	9.139				
		120-6A	2.050	0.058	13.915				
	121A								
121	12/17/92	LAMINATES							
	[redacted] (7/92)	80% LOADING [redacted]							
	WASHED 3 TIMES	MICROTHENE (5/92)							
	NO HEAT	.25% CAPOW L38/H							
		HAND COMPOUNDED							
		CARBON PLASTIC							
		121-1A	0.430	0.075	2.257				
		121-2A	0.430	0.070	2.418				
	122A								
122A	12/17/92	LAMINATES							
	CARBON PLASTIC	2.60G KETBLACK							
	POWDER PRESSED	10.37G MICRO (5/92)							
	TO PRECOMPOUNDED	325F/15 TONS							
	85% [redacted] SHEET	0.060" SHIM							
		122-1A	0.460	0.051	3.551	1.400	0.051	10.807	204.348
		122-2A	0.430	0.050	3.386	5.400	0.051	41.606	1131.190

REVISED- 16-FEB-1993

STABILITY TESTING

SAMPLE NO.	DATE	MATERIAL COMPOSITION	RESISTANCE (OHM) BEFORE	THICKNESS (INCH) BEFORE	RESISTIVITY (OHM-CM) BEFORE	RESISTANCE (OHM) AFTER	THICKNESS (INCH) AFTER	RESISTIVITY (OHM-CM) AFTER	PERCENT CHANGE (%)
	85% [redacted]	122-3A	0.410	0.050	3.220	1.450	0.051	11.193	246.724
	PELLETS PRESSED	122-4A	0.430	0.052	3.256	0.820	0.052	6.208	90.698
	TO HANDCOMPOUNDED								
	CARBON PLASTIC SHEET								
	123A								
123A	01/04/93	LAMINATES							
VARY % CAPOW	CAPOW[redacted]	80% LOADING [redacted]							
	MIXED FIRST	(7/92) H2O WASHED							
	THEN MICROTHENE	20% MICROTHENE							
		HANDCOMPOUNDED							
	MIXED IN LARGE	C-PLASTIC							
	8 OZ. MORTAR	.30% TO 1.00% CAPOW							
	AND PEDISTAL	L38/H							
		325F/3 TONS							
		123-1A (.30%)	0.490	0.080	2.411	0.580	0.080	2.854	18.367
		123-2A (.35%)	0.360	0.081	1.750	0.370	0.081	1.798	2.778
		123-3A (.40%)	0.580	0.080	2.854	0.740	0.081	3.597	26.011
		123-4A (.45%)	0.430	0.081	2.090	0.510	0.080	2.510	20.087
		123-5A (.50%)	0.440	0.078	2.221				
		123-6A (.55%)	0.650	0.078	3.281				
		123-7A (.60%)	0.620	0.076	3.212				
		123-8A (.65%)	0.600	0.076	3.108				
		123-9A (.70%)	0.660	0.078	3.331				
		123-10A (.75%)	0.600	0.076	3.108				
		123-11A (.80%)	0.900	0.080	4.429				
		123-12A (.85%)	0.680	0.080	3.346				
		123-13A (.90%)	0.600	0.072	3.281				
		123-14A (.95%)	0.520	0.075	2.730				
		123-15A (1.00%)	0.540	0.075	2.835				
	124A	LAMINATES							
	07-JAN-93	80% LOADING[redacted]							
		(7/92) H2O WASHED							
	CAPOW[redacted]	20% MICROTHENE							
	MIXED FIRST	HANDCOMPOUNDED							
	THEN MICROTHENE	C-PLASTIC							
		1.5% TO 3.0% CAPOW							
	MIXED IN LARGE	L38/H							
	8 OZ. MORTAR	325F/3 TONS							
	AND PEDISTAL	124-1A (1.5%)	0.620	0.075	3.255				
		124-2A (2.0%)	0.980	0.077	5.011				
		124-3A (2.5%)	0.830	0.076	4.300				
		124-4A (3.0%)	0.660	0.077	3.375				
125A	125A	LAMINATES							
	01/12/93	TEMP 230F TO 400F							
	VARYING PRESS	85% [redacted] PELLETS							
	TEMPERATURES OF	HANDCOMPOUNDED							
	PRECOMPOUNDED	C-PLASTIC							
	85% [redacted]	125-1A (300F)	0.410	0.057	2.832				
	FROM [redacted]	125-2A (300F)	0.730	0.057	5.042				
		[illegible]	[illegible]	[illegible]	[illegible]				

STABILITY TESTING

SAMPLE NO.	DATE	MATERIAL COMPOSITION	RESISTANCE (OHM) BEFORE	THICKNESS (INCH) BEFORE	RESISTIVITY (OHM-CM) BEFORE	RESISTANCE (OHM) AFTER	THICKNESS (INCH) AFTER	RESISTIVITY (OHM-CM) AFTER	PERCENT CHANGE (%)
		125-5A (375F)	0.450	0.051	3.474				
		125-6A (375F)	0.440	0.052	3.331				
		125-7A (400F)	0.390	0.051	3.011				
		125-8A (400F)	0.390	0.051	3.011				
		125-11A (275F)	0.580	0.057	4.006				
		125-12A (275F)	0.380	0.057	2.625				
	126A	LAMINATES							
	01/14/93	80% TO 90% LOADING							
		[redacted](7/92)							
	DIFFERENT %	.35% CAPOW L38/H							
	OF [redacted] LOADINGS	SAMPLES 1&2							
		.30% CAPOW L38/H							
	NEW BAG MICROTHENE	SAMPLES 3-7							
	(10/92)	HANDCOMPOUNDED							
		C-PLASTIC							
		MICROTHENE (5/92)							
		325F/3 TONS							
		126-1A (80%)	1.450	0.061	9.358				
		126-2A (80%)	2.850	0.061	18.394				
		126-3A (85%)	0.32	0.08	1.575	0.4	0.08	1.969	25.000
	PRESS UPSIDE DOWN	126-4A (85%)	0.27	0.076	1.399	0.33	0.076	1.709	22.222
		275F/3 TONS							
		126-6A (82.5%)	1.4	0.073	7.550	1.45	0.073	7.820	3.571
	PRESS UPSIDE DOWN	126-7A (82.5%)	0.52	0.062	3.302	0.53	0.062	3.366	1.923
	[redacted] SIDE DOWN								
129A	01/15/93	LAMINATES							
		85% [redacted] PELLETS							
DIFFERENT %	85% [redacted]	14% TO 22%							
KETJENBLACK	PELLETS	KETJENBLACK (9/92)							
	FROM [redacted]	325F/3 TONS							
		129-1A (15%)	0.54	0.05	4.252				
		129-2A (15%)	0.64	0.048	5.249				
		129-3A (16%)	0.55	0.049	4.419				
		129-4A (16%)	0.56	0.049	4.499				
		129-5A (16%)	0.75	0.05	5.906				
		129-6A (18%)	0.66	0.049	5.303				
		129-7A (22%)	0.63	0.051	4.863				
		129-8A (22%)	0.38	0.05	2.992				
130A	130A	LAMINATE 325F/3 TONS							
	01/19/93	130-1A (18%)	0.46	0.049	3.696	0.71	0.049	5.705	54.348
		130-2A (18%)	0.46	0.044	4.116	0.76	0.045	6.649	61.546
	16% AND 18%	130-3A (16%)	0.43	0.044	3.848	0.53	0.044	4.742	23.256
	KETJENBLACK(9/92)	130-4A (16%)	0.49	0.043	4.486	0.64	0.044	5.727	27.644
	NEW MICRO(10/92)								
	325F/3 TONS								
	85% [redacted] PELLETS								
	FROM [redacted]								
131A	131A	LAMINATE 325F/3 TONS							
	01/27/93	131-1A(3 TONS)	0.58	0.061	3.743				
	85% [redacted](7/92)	131-3A(15 TONS)	0.74	0.055	5.297				
	[illegible]	131-4A(15 TONS)	0.51	0.052	3.861				

REVISED- 16-FEB-1993 STABILITY TESTING

SAMPLE NO.	DATE	MATERIAL COMPOSITION	RESISTANCE (OHM) BEFORE	THICKNESS (INCH) BEFORE	RESISTIVITY (OHM-CM) BEFORE	RESISTANCE (OHM) AFTER	THICKNESS (INCH) AFTER	RESISTIVITY (OHM-CM) AFTER	PERCENT CHANGE (%)
	AND 15 TONS	131-5A(3 TONS)	0.78	0.076	4.041				
	16% C-PLASTIC								
132A	132A	LAMINATE 325F/3 TONS							
	01/28/93	132-1A(3 TONS)	1.3	0.057	8.979				
	82.5% [redacted](7/92)	132-2A(3 TONS)	1.5	0.048	12.303				
	PRESSED AT 3 TONS	132-3A(15 TONS)	0.96	0.05	7.559				
	AND 15 TONS	132-4A(15 TONS)	0.79	0.051	6.099				
	16% C-PLASTIC								
133A	133A	LAMINATE 325F/3 TONS							
	01/28/93	133-1A(3 TONS)	0.36	0.069	2.054				
	85% [redacted](7/92)	133-2A(3 TONS)	0.32	0.065	1.938				
	PRESSED AT 3 TONS	133-3A(15 TONS)	0.44	0.051	3.397				
	AND 15 TONS	133-4A(15 TONS)	0.5	0.052	3.786				
	18% C-PLASTIC								
134A	134A	LAMINATE 325F/3 TONS							
	01/28/93	134-1A(3 TONS)	0.76	0.058	5.159	0.83	0.058	5.634	9.211
	82.5% [redacted](7/92)	134-2A(3 TONS)	0.63	0.057	4.351	0.69	0.058	4.684	7.635
	PRESSED AT 3 TONS	134-3A(15 TONS)	0.85	0.049	6.830	0.72	0.049	5.785	-15.294
	AND 15 TONS	134-4A(15 TONS)	0.76	0.051	5.867	0.68	0.05	5.354	-8.737
	18% C-PLASTIC								
135A	01/28/93	LAMINATE 325F/3 TONS							
		135-1A(.010")	0.65	0.029	8.824	0.61	0.03	8.005	-9.282
	THIN [redacted](85%) AND	135-2A(.010")	0.6	0.034	6.948	0.57	0.034	6.600	-5.000
	C-PLASTIC(18%)	135-3A(.006")	0.56	0.029	7.602	0.51	0.029	6.924	-8.929
	.010" AND .006"	135-4A(.006")	0.62	0.029	8.417	0.72	0.029	9.775	16.129
	SHIMS								
136A	02/01/93	LAMINATE 325F/3 TONS							
		136-1A(22%)	0.39	0.034	4.516				
	22% AND 24%	136-2A(22%)	0.57	0.033	6.808				
	C-PLASTIC	136-3A(24%)	0.34	0.035	3.825				
	THIN [redacted](85%)	136-4A(24%)	0.39	0.034	4.516				
137A	02/03/93	LAMINATE 325F/3 TONS							
		137-1A	0.24	0.041	2.305				
	87% [redacted](7/92)	137-2A	0.235	0.043	2.152				
		137-3A	0.305	0.042	2.859				
	18% AND 22%	137-4A	0.215	0.043	1.969				
	C-PLASTIC								
[redacted]	02/03/93	LAMINATE 325F/3 TONS							
	85% [redacted] PELLETS								
	FROM [redacted]	MRP-1	0.48	0.056	3.375	0.59	0.056	4.148	22.917
FIRST RUN	18% C-PLASTIC	MRP-2	0.41	0.061	2.646	0.40	0.06	3.150	19.024
FROM [redacted]	0.030" THICK	MRP-3	0.49	0.054	3.572	0.53	0.054	3.864	8.163
		MRP-4	0.43	0.058	2.919	0.47	0.058	3.190	9.302

REVISED- 12-MAR-1993

STABILITY TESTING

SAMPLE NO.	DATE	MATERIAL COMPOSITION	RESISTANCE (OHM) BEFORE	THICKNESS (INCH) BEFORE	RESISTIVITY (OHM-CM) BEFORE	RESISTANCE (OHM) AFTER	THICKNESS (INCH) AFTER	RESISTIVITY (OHM-CM) AFTER	PERCENT CHANGE (%)
		138-1A	0.34	0.03	4.462				
	DUPLICATE OF 135A	138-2A	0.6	0.032	7.382				
	85% [redacted] (THIN)	138-3A	0.43	0.036	4.703				
	18% C-PLASTIC	138-4A	0.35	0.035	3.937				
	(THIN)								
139A	02/05/93	LAMINATE 325F/3 TONS							
	85% [redacted] PELLETS	139-1A(18%)	0.39	0.022	6.979	4.8	0.022	85.898	1130.769
	FROM [redacted]/NO SHIM	139-2A(18%)	0.36	0.025	5.669	5.8	0.024	95.144	1578.241
	18 & 22% C-PLASTIC	139-3A(22%)	0.33	0.026	4.997	1.95	0.026	29.528	490.909
	PRESSED TWICE	139-4A(22%)	0.4	0.027	5.833	1.65	0.027	24.059	312.500
BR AND R3	02/05/93	LAMINATE 325/3 TONS							
		BR-1	0.76	0.039	7.672	1.15	0.039	11.609	51.316
C-PLASTIC	85% [redacted] PELLETS	BR-2	0.85	0.039	8.581	1.15	0.039	11.609	35.294
FROM ZNBR	FROM [redacted]								
	BR-1 AND BR-2								
	85% [redacted]	R3-1	0.47	0.042	4.406	0.81	0.042	7.593	72.340
16% PLUS 24%	HANDCOMPOUNDED	R3-2	0.51	0.049	4.098	1.1	0.049	8.838	115.686
C-PLASTIC	R3-1 AND R3-2								
	3 PIECE LAMINATE								
142A	02/11/93	LAMINATE 325F/3 TONS							
		142-1A(1%)	0.135	0.033	1.611	24.5	0.035	275.591	17011.111
1,3 AND 5%	85% [redacted]	142-2A(1%)	0.12	0.033	1.432	38	0.032	467.520	32556.250
STEARIC ACID		142-3A(3%)	0.115	0.033	1.372				
	C-PLASTIC	142-4A(3%)	0.102	0.033	1.217				
	PELLETS(2/93)	142-5A(5%)	0.115	0.032	1.425				
		142-6A(5%)	0.14	0.033	1.670				
143A	02/12/93	LAMINATE 325F/3 TONS							
		143-1A(3%)	0.102	0.036	1.115	68	0.032	836.614	74900.000
3,6 AND 10%	85% [redacted]	143-2A(3%)	0.102	0.037	1.085	27.5	0.036	300.744	27609.695
PARAFFIN OIL		143-3A(6%)	0.13	0.036	1.422				
	C-PLASTIC	143-4A(6%)	0.115	0.037	1.224				
	PELLETS(2/93)	143-5A(10%)	0.098	0.035	1.102				
		143-6A(10%)	0.1	0.035	1.125				
144A	02/12/93	LAMINATE 325F/3 TONS							
	85% [redacted]	144-1A	0.170	0.030	2.231	0.270	0.030	3.543	58.824
.30% CAPOW	1% STEARIC ACID	144-2A	0.210	0.029	2.851	0.255	0.029	3.462	21.429
	3% PARAFFIN OIL								
	22% C-PLASTIC	144-3A	0.160	0.028	2.250	0.210	0.028	2.953	31.250
	PELLETS (2/93)	144-4A	0.190	0.029	2.579	0.215	0.029	2.919	13.158
146A	02/12/93	LAMINATE 325F/3 TONS							
		146-1A(10%)	0.16	0.024	2.625				
10% PARAFFIN	82.5% [redacted]	146-2A(10%)	0.14	0.025	2.205				
OIL		146-3A(3%)	0.145	0.025	2.283				
	C-PLASTIC	146-4A(3%)	0.155	0.025	2.441				
3% STEARIC	PELLETS(2/93)								
ACID									
147A	02/16/93	LAMINATE 325F/3 TONS							

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STABILITY TESTING

SAMPLE NO.	DATE	MATERIAL COMPOSITION	RESISTANCE (OHM) BEFORE	THICKNESS (INCH) BEFORE	RESISTIVITY (OHM-CM) BEFORE	RESISTANCE (OHM) AFTER	THICKNESS (INCH) AFTER	RESISTIVITY (OHM-CM) AFTER	PERCENT CHANGE (%)
	85% [redacted] SHEET	147-1A	0.66	0.041	6.338	20.5	0.041	196.850	3006.061
SECOND RUN	FROM MRP	147-2A	0.86	0.049	6.910	44.5	0.049	357.545	5074.419
FROM MRP	22% C-PLASTIC	147-3A	0.78	0.043	7.142	3.8	0.043	34.792	387.179
	PELLETS(2/93)	147-4A	0.44	0.049	3.535	1.1	0.049	8.838	150.000
148A	02/17/93	LAMINATE 325F/3 TONS							
	86% LOADING	148-1A(3%)	0.105	0.037	1.117				
	3% STEARIC ACID	148-2A(3%)	0.089	0.039	0.898				
	6% PARAFFIN OIL	148-3A(6%)	0.1	0.043	0.916				
	22% C-PLASTIC	148-4A(6%)	0.12	0.049	0.964				
	PELLETS								
149A	02/17/93	LAMINATE 325F/3 TONS							
	86% LOADING	149-1A(3%)	0.275	0.032	3.383				
.3% CAPOW	3% STEARIC ACID	149-2A(3%)	0.175	0.033	2.088				
		149-3A(6%)	0.210	0.032	2.584				
	6% PARAFFIN OIL	149-4A(6%)	0.185	0.033	2.207				
	22% C-PLASTIC								
	PELLETS								
150A	02/18/93	LAMINATE 325F/3 TONS							
	85% [redacted] PELLETS	150-1A	0.350	0.025	5.512				
PELLETS	FROM [redacted]	150-2A							
	25G SAMPLE								
	C-PLASTIC PELLETS								
151A	02/19/93	LAMINATE 325F/3TONS							
GRID PATTERN	85% [redacted]	151-1A	0.2	0.039	2.019	0.34	0.042	3.187	57.857
PRESSED IN	HANDCOMPOUNDED	151-2A	0.205	0.043	1.877	0.32	0.045	2.800	49.160
LAMINATE		151-3A	0.245	0.042	2.297				
	C-PLASTIC	151-4A	0.225	0.043	2.060				
	PELLETS.								
152A	02/19/93	LAMINATE 325F/3TONS							
GRID PATTERN	85% [redacted]	152-1A	0.380	0.035	4.274	0.960	0.042	8.999	110.526
PRESSED IN	SHEET FROM MRP	152-2A	0.450	0.039	4.543	1.050	0.039	10.600	133.333
LAMINATE									
	C-PLASTIC PELLETS								
153A	02/22/93	LAMINATE 325F/3TONS							
	82.5% [redacted]	153-1A(3%)	0.300	0.018	6.562				
82.5% [redacted]	3% PARAFFIN	153-2A(3%)	0.500	0.026	7.571				
	.30% CAPOW L38 H								
	1% STEARIC ACID	153-3A(1%)	0.530	0.026	8.025				
	.30% CAPOW L38 H	153-4A(1%)	0.400	0.026	6.057				
	C-PLASTIC PELLETS								
154A	02/23/93	LAMINATE 325F/3TONS							
	85% [redacted]	154-1A(1%)	0.580	0.028	8.155	0.740	0.028	10.405	27.586
[redacted] WASHED	1% STEARIC ACID	154-2A(1%)	0.320	0.027	4.666	0.410	0.027	5.978	28.125

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STABILITY TESTING

SAMPLE NO.	DATE	MATERIAL COMPOSITION	RESISTANCE (OHM) BEFORE	THICKNESS (INCH) BEFORE	RESISTIVITY (OHM-CM) BEFORE	RESISTANCE (OHM) AFTER	THICKNESS (INCH) AFTER	RESISTIVITY (OHM-CM) AFTER	PERCENT CHANGE (%)
	W/ 1% CAPOW L38/H								
& 1% CAPOW	3% PARAFFIN	154-3A(3%)	0.400	0.027	5.833	0.570	0.029	7.738	32.672
		154-4A(3%)	0.275	0.027	4.010	0.430	0.029	5.838	45.500
	C-PLASTIC PELLETS								
155A	02/25/93	LAMINATE 325F/3TONS							
	85% [redacted] (HEXANE WASH)								
[redacted] WASHED		155-1A	0.160	0.034	1.853	9.200	0.035	103.487	5485.714
WITH HEXANE	C-PLASTIC PELLETS	155-2A	0.155	0.034	1.795	[illegible].400	0.034	108.847	5964.516
NO CAPOW									
156A	02/25/93	LAMINATE 325F/3TONS							
	SAME AS 85% [redacted]								
85% [redacted]	PELLETS FROM [redacted]	156-1A	0.550	0.025	8.661				
SLUGS FROM		156-2A	0.480	0.026	7.268				
[redacted]	C-PLASTIC PELLETS								
157A	02/26/93	LAMINATE 325F/3TONS							
		0.031" SHIMS							
.5% CAPOW	85% [redacted]	157-1A(1%)	0.580	0.031	7.366	0.960	0.031	12.192	65.517
	1% STEARIC ACID	157-2A(1%)	0.235	0.030	3.084	0.420	0.030	5.512	78.723
	3% PARAFFIN OIL	157-31(3%)	0.310	0.031	3.937	0.470	0.031	5.969	51.613
	C-PLASTIC PELLETS	157-4A(3%)	0.215	0.030	2.822	0.340	0.030	4.462	58.140
158A	02/26/93	LAMINATE 325F/3TONS							
		0.031" SHIMS							
.3% CAPOW	85% [redacted]	158-1A(1%)	0.235	0.039	2.372				
GRID PATTERN	1% STEARIC ACID	158-2A(1%)	0.210	0.042	1.969				
PRESSED IN									
LAMINATE	3% PARAFFIN OIL	158-3A(3%)	0.230	0.039	2.322				
	C-PLASTIC PELLETS	158-4A(3%)	0.245	0.039	2.473				
	*PARAFFIN LAMINATE STUCK TO GRID MOLD								
159A	03/08/93	LAMINATE 325F/3TONS							
		159-1A(STABILITY)	0.380	0.073	2.049	[illegible]	[illegible]	[illegible]	[illegible]
LAMINATE	82.5% LOADING	159-2A(BATTERY)	0.400	0.086	1.831				
FOR 4V	.35% CAPOW	159-3A(STABILITY)	0.420	0.086	1.923	[illegible]	[illegible]	[illegible]	[illegible]
BATTERY		159-4A(BATTERY)	0.370	0.087	1.674				
	C-PLASTIC PELLETS								
160A	03/08/93	LAMINATE 325F/3TONS							
		[illegible]0-1A(STABILITY)	0.740	0.085	3.428	[illegible]	[illegible]	[illegible]	[illegible]
LAMINATE	80% LOADING	[illegible]0-2A(STABILITY)	0.840	0.085	3.891	[illegible]	[illegible]	[illegible]	[illegible]
FOR 4V	.35% CAPOW								
BATTERY		160-3A(BATTERY)	0.670	0.084	3.140				
	C-PLASTIC PELLETS	160-4A(BATTERY)	0.570	0.086	2.609				

REVISED- 05-APR-1993

STABILITY TESTING

SAMPLE NO.	DATE	MATERIAL COMPOSITION	RESISTANCE (OHM) BEFORE	THICKNESS (INCH) BEFORE	RESISTIVITY (OHM-CM) BEFORE	RESISTANCE (OHM) AFTER	THICKNESS (INCH) AFTER	RESISTIVITY (OHM-CM) AFTER	PERCENT CHANGE (%)
161A	03/15/93	LAMINATE 325F/3TONS							
FIRST RUN	85% LOADING	161-1A(.050")	0.780	0.055	5.583	1.400	0.056	9.843	76.282
OF 85% [redacted]	.024" & .050"	161-2A(.050")	0.620	0.054	4.520				
FROM THE	EXTRUDED IN-HOUSE								
EXTRUDER		161-3A(.025")	0.580	0.035	6.524				
	C-PLASTIC PELLETS	161-4A(.025")	0.620	0.037	6.597	5.400	0.038	55.947	748.048
162A	03/17/93	LAMINATE 325F/3TONS							
	85% [redacted] SHEET	162-1A	0.480	0.032	5.906	12.000	0.033	143.164	2324.242
MRP SAMPLE	FROM MRP	162-2A	0.480	0.036	5.249	1.350	0.037	14.365	173.649
RECEIVED		162-3A	0.480	0.036	5.249				
3/17/93	C-PLASTIC PELLETS	162-4A	0.540	0.032	6.644				
163A	03/22/93	LAMINATE 325F/3TONS							
85% [redacted]	SAMPLE EXTRUDED	163-1A	0.970	0.037	10.321	>100	0.036		
FROM IN-	3/18/93	163-2A	0.680	0.037	7.236	61.000	0.036	667.104	9119.771
HOUSE									
EXTRUDER	C-PLASTIC PELLETS								
164A	03/22/93	LAMINATE 325F/3 TONS							
85% [redacted]	RECEIVED 3/19/93	164-1A	0.550	0.032	6.767	18.500	0.031	234.950	3372.141
FROM MRP		164-2A	0.760	0.033	9.067	15.500	0.033	184.920	1939.470
	C-PLASTIC PELLETS								
165A	03/22/93	LAMINATE 325F/3 TONS							
EXTRUDED	85% LOADING	165-1A	0.800	0.032	9.843	0.840	0.031	10.668	8.387
3/22/93	.35% CAPOW	165-2A	0.780	0.031	9.906	0.780	0.030	10.236	3.333
	100/110/120/125								
	C-PLASTIC PELLETS								
166A	03/23/93	LAMINATE 325F/3 TONS							
EXTRUDED	85% LOADING	166-1A	0.590	0.039	5.956	0.700	0.039	7.066	18.644
3/23/93	.35% CAPOW	166-2A	0.700	0.038	7.252	0.740	0.038	7.667	5.714
	1% STEARIC ACID								
	100/110/120/125								
	C-PLASTIC PELLETS								
167A	03/24/93	LAMINATE 325F/3 TONS							
EXTRUDED	85% LOADING	167-1A	0.730	0.036	7.983				
3/24/93	.35% CAPOW L38/H	167-2A	0.820	0.039	8.278				
	100/105/105/105								
	C-PLASTIC PELLETS								

REVISED- 06-MAY-1993 STABILITY TESTING

SAMPLE NO.	DATE	MATERIAL COMPOSITION	RESISTANCE (OHM) BEFORE	THICKNESS (INCH) BEFORE	RESISTIVITY (OHM-CM) BEFORE	RESISTANCE (OHM) AFTER	THICKNESS (INCH) AFTER	RESISTIVITY (OHM-CM) AFTER	PERCENT CHANGE (%)
EXTRUDED	85% LOADING	168-1A	1.200						
3/24/93	.35% CAPOW L38/H	100/115/120/125							
	10% PARAFFIN OIL	168-2A	IR too high.						
VARYING		100/110/120/125	Lamination						
TEMP.	C-PLASTIC PELLETS	168-3A	stopped.						
		100/110/115/115							
169A	03/25/93	LAMINATE 325F/3 TONS							
EXTRUDED	85% LOADING	169-1A	0.890	0.041	8.546	>100			
3/25/93	NO CAPOW/ADDITIVES	169-2A	0.520	0.041	4.993	>100			
HIGH TEMP	C-PLASTIC PELLETS								
170A	03/26/93	LAMINATE 325F/3 TONS							
EXTRUDED	85% LOADING	170-1A	0.680	0.041	6.530	0.660	0.041	6.338	-2.941
3/26/93	.35% CAPOW L38/H	170-2A	0.900	0.041	8.642	0.860	0.041	8.258	-4.444
HIGH TEMP	C-PLASTIC PELLETS								
171A	03/30/93	LAMINATE 325F/3 TONS							
MRP	85% [redacted]	171-1A	0.350	0.035	3.937	0.740	0.035	8.324	111.429
RECEIVED	VACUUM PRESSED	171-2A	0.680	0.035	7.649	1.050	0.036	11.483	50.123
3/25/93	PELLETS FROM	171-3A	0.520	0.039	5.249				
		171-4A	0.550	0.038	5.698				
	C-PLASTIC PELLETS								
172A	03/31/93	LAMINATE 325F/3 TONS							
EXTRUDED	85% [redacted]	172-1A	0.460	0.045	4.024	0.530	0.045	4.637	15.217
3/31/93	.35% CAPOW L38/H	172-2A	0.560	0.045	4.899	0.800	0.045	6.999	42.857
	100/130/150/160								
HIGH TEMP	C-PLASTIC PELLETS								
173A	04/2/93	LAMINATE 325F/3 TONS							
EXTRUDED	85% [redacted]	173-1A	0.340	0.039	3.432	0.360	0.040	3.543	3.235
4/2/93	.35% CAPOW L38/H	173-2A	0.410	0.039	4.139	0.480	0.042	4.609	11.362
	100/140/160/180								
	C-PLASTIC PELLETS								
174A	04/3/93	LAMINATE 325F/3 TONS							
EXTRUDED	85% [redacted]	174-1A	0.410	0.039	4.139	0.400	0.040	3.937	-4.878
4/2/93	.35% CAPOW L38/H	174-2A	0.425	0.037	4.522	0.480	0.040	4.724	4.471
	100/160/180/200								
	C-PLASTIC PELLETS								
175A	04/05/93	LAMINATE 325F/3 TONS							
EXTRUDED	85% [redacted]	175-1A(160)	0.550	0.041	5.281	0.790	0.042	7.586	43.636

REVISED- 06-MAY-1993

STABILITY TESTING

SAMPLE NO.	DATE	MATERIAL COMPOSITION	RESISTANCE (OHM) BEFORE	THICKNESS (INCH) BEFORE	RESISTIVITY (OHM-CM) BEFORE	RESISTANCE (OHM) AFTER	THICKNESS (INCH) AFTER	RESISTIVITY (OHM-CM) AFTER	PERCENT CHANGE (%)
4/5/93	.35% CAPOW L38/H	175-2A(160)	0.390	0.042	3.656	0.530	0.042	4.968	35.897
	3% STEARIC ACID								
	100/130/150/160	175-3A(180)	0.470	0.043	4.303	0.680	0.043	6.226	44.681
VARY EXTR. TEMP	100/140/160/180	175-4A(180)	0.440	0.042	4.124	0.580	0.043	5.310	28.753
	C-PLASTIC PELLETS								
176A	04/06/93	LAMINATE 325F/3 TONS							
EXTRUDED 4/5/93	85% [redacted]	176-1A(160)	0.420	0.040	4.134	0.430	0.040	4.232	2.381
	.35% CAPOW L38/H	176-2A(160)	0.490	0.040	4.823	0.490	0.041	4.705	-2.439
	10% PARAFFIN OIL								
	100/130/150/160	176-3A(180)	0.380	0.039	3.836	0.390	0.039	3.937	2.632
VARY EXTR. TEMP	100/140/160/180	176-4A(180)	0.350	0.038	3.626	0.360	0.040	3.543	-2.286
	C-PLASTIC PELLETS								
177A	04/12/93	LAMINATE 325F/3 TONS							
EXTRUDED 4/5/93	85% [redacted]	177-1A(160)	0.610	0.041	5.857	0.530	0.041	5.089	-13.115
	.35% CAPOW L38/H	177-2A(160)	0.810	0.044	7.248	0.740	0.042	6.937	-4.292
	10% PARAFFIN OIL								
	100/130/150/160	177-3A(180)	1.050	0.043	9.614	0.770	0.042	7.218	-24.921
	100/140/160/180	177-4A(180)	0.840	0.044	7.516	0.650	0.043	5.951	-20.819
IN-HOUSE EXTRUDED C-PLASTIC	19% C-PLASTIC 100/140/160/180								
178A	04/14/93	LAMINATE 325F/3 TONS							
	85% [redacted]								
EXTRUDED 3/31/93	.35% CAPOW L38/H	178-1A(160)	0.540	0.046	4.622	0.580	0.046	4.964	7.407
AND	100/130/150/160	178-2A(160)	0.640	0.047	5.361	0.680	0.045	5.949	10.972
4/2/93	100/140/160/180	178-3A(180)	0.530	0.045	4.637	0.480	0.045	4.199	-9.434
		178-4A(180)	0.450	0.041	4.321	0.480	0.041	4.609	6.667
IN-HOUSE EXTRUDED C-PLASTIC	19% C-PLASTIC 100/140/160/180								
179A	04/15/93	LAMINATE 325F/3 TONS							
	85% [redacted]								
SANDED	.35% CAPOW L38/H	179-1A(160)	0.390	0.045	3.412	0.460	0.045	4.024	17.949
SUBSTRATE	100/130/150/160	179-2A(160)	0.310	0.043	2.838	0.390	0.043	3.571	25.806
AND	EXTRUDED 3/31/93								
C-PLASTIC	100/140/160/180	179-3A(180)	0.280	0.043	2.564	0.340	0.043	3.113	21.429
BEFORE LAMINATION	EXTRUDED 4/2/93	179-4A(180)	0.310	0.043	2.838	0.380	0.043	3.479	22.581
IN-HOUSE EXTRUDED C-PLASTIC	19% C-PLASTIC 100/140/160/180								
180A	04/16/93	LAMINATE 325F/3 TONS							
	85% [redacted]								
SANDED	10% PARAFFIN OIL	180-1A(160)	0.300	0.041	2.881	0.390	0.042	3.656	26.905
			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3.212	16.901

REVISED- 17-MAY-1993

STABILITY TESTING

SAMPLE NO.	DATE	MATERIAL COMPOSITION	RESISTANCE (OHM) BEFORE	THICKNESS (INCH) BEFORE	RESISTIVITY (OHM-CM) BEFORE	RESISTANCE (OHM) AFTER	THICKNESS (INCH) AFTER	RESISTIVITY (OHM-CM) AFTER	PERCENT CHANGE (%)
AND	100/130/150/160								
C-PLASTIC	100/140/160/180	180-3A(180)	0.310	0.039	3.129	0.390	0.039	3.937	25.806
BEFORE	EXTRUDED 4/5/93	180-4A(180)	0.280	0.037	2.979	0.320	0.039	3.230	8.425
LAMINATION									
	19% C-PLASTIC								
IN-HOUSE	100/140/160/180								
EXTRUDED									
C-PLASTIC									
181A	04/28/93	LAMINATE 325F/3 TONS							
	85% [redacted]								
SISTER TO	10% PARAFFIN OIL	181-1A(200)	0.470	0.063	2.937	0.580	0.062	3.683	25.395
4V BATTERY	.5% CAPOW	181-2A(200)	0.400	0.059	2.669	0.560	0.057	3.868	44.912
LAMINATE									
		181-3A(180)	0.540	0.064	3.322	0.610	0.064	3.752	12.963
		181-4A(180)	0.550	0.064	3.383	0.580	0.064	3.568	5.455
IN-HOUSE	19% C-PLASTIC								
EXTRUDED	100/140/160/180								
C-PLASTIC									
182A	04/28/93	LAMINATE 325F/3 TONS							
4V BATTERIES	85% [redacted]								
FOR PASTE	10% PARAFFIN OIL	182-1A(200)	0.680	0.073	3.667				
ADHESION	.5% CAPOW	SANDED							
STUDIES		182-2A(200)	0.700	0.060	4.593				
		Pb THEN SANDED							
	19% C-PLASTIC	182-3A(180)	0.680	0.071	3.771				
		SANDED							
		182-4A(180)	0.600	0.058	4.073				
		Pb THEN SANDED							
			IR readings taken at corner of laminate.						
183A	04/29/93	LAMINATE 325F/3 TONS							
	85% [redacted]	183-1A	0.380	0.043	3.479	0.540	0.044	4.832	38.876
	10% PARAFFIN OIL	183-2A	0.380	0.043	3.479	0.550	0.048	4.511	29.660
HEXANE WASH	.35% CAPOW	183-3A	0.380	0.059	2.536	0.550	0.059	3.670	44.737
EXTRUDED		183-4A	0.380	0.057	2.625	0.580	0.059	3.870	47.450
4/29/93	19% C-PLASTIC								
184A	05/04/93	LAMINATE 325F/3 TONS							
	80% [redacted]	184-1A	0.580	0.046	4.964	0.780	0.046	6.676	34.483
[redacted]	.35% CAPOW	184-2A	0.500	0.046	4.279	0.800	0.047	6.701	56.596
	HANDCOMPOUNDED	184-3A	0.580	0.050	4.567	0.760	0.051	5.867	28.465
	NOT SANDED								
	19% C-PLASTIC								
185A	05/05/93	LAMINATE 325F/3 TONS							
	82.5% [redacted]	185-1A	0.380	0.055	2.720	0.580	0.055	4.152	52.632
[redacted]	.35% CAPOW	185-2A	0.290	0.048	2.379	0.410	0.050	3.228	35.724
	HANDCOMPOUNDED	THICK SUBSTRATE							
	NOT SANDED								
	19% C-PLASTIC								

REVISED- 15-JUL-1993 STABILITY TESTING

SAMPLE NO.	DATE	MATERIAL COMPOSITION	RESISTANCE (OHM) BEFORE	THICKNESS (INCH) BEFORE	RESISTIVITY (OHM-CM) BEFORE	RESISTANCE (OHM) AFTER	THICKNESS (INCH) AFTER	RESISTIVITY (OHM-CM) AFTER	PERCENT CHANGE (%)
	85% [redacted]								
	.35% CAPOW	186-1A	1.000	0.041	9.602	1.550	0.042	14.529	51.310
	10% PARAFFIN OIL	186-2A	0.820	0.041	7.874	1.300	0.043	11.903	51.163
	NOT SANDED								
	19% C-PLASTIC								
187A	85% [redacted]	LAMINATE 330F/2 TONS							
	0.008" RIBBON	187-1A	0.155	0.030	2.034	10.500	0.030	137.795	6674.194
RIBBON	PRESSED ON	187-2A	0.135	0.029	1.833	20.000	0.029	271.518	14714.815
REC' 5/17/93	HAND PRESS	187-3A	0.135	0.029	1.833	6.200	0.029	84.171	4492.593
		187-4A	0.155	0.030	2.034	8.100	0.030	106.299	5125.806
	19% C-PLASTIC								
188A	85% [redacted]	LAMINATE 330F/2 TONS							
	0.010" RIBBON	188-1A	0.140	0.028	1.969	6.000	0.030	78.740	3900.000
RIBBON	PRESSED ON	188-2A	0.140	0.031	1.778	9.000	0.030	118.110	6542.857
REC' 5/17/93	HAND PRESS	188-3A	0.135	0.031	1.715	8.100	0.031	102.870	5900.000
		188-4A	0.155	0.031	1.969	9.600	0.031	121.920	6093.548
	19% C-PLASTIC								
189A	06/14/93	LAMINATE 295F/3 TONS							
	85% [redacted]	189-1A	0.970	0.045	8.486				
EXTRUDED	.35% CAPOW								
06/14/93		IR OF SAMPLE WAS TOO HIGH. NEW SAMPLES WILL BE MADE AND TESTED							
	19% C-PLASTIC	189-3A(SANDED)	0.470	0.051	3.628	0.700	0.051	5.404	48.936
		189-4A(SANDED)	0.540	0.045	4.724	0.830	0.045	7.262	53.704
190A	06/16/93	LAMINATE 295F/3 TONS							
	85% [redacted]	190-1A	0.740	0.086	3.388				
4V BATTERY	.35% CAPOW L38/H	190-2A	0.780	0.092	3.338				
SUBSTRATES		190-3A	0.730	0.086	3.342				
		190-4A	0.660	0.086	3.021				
EXTRUDED	19% C-PLASTIC								
04/2/93									
191A	06/18/93	LAMINATE 295F/3 TONS							
	85% [redacted]	191-1A(006)SANDED	0.250	0.044	2.237	1.600	0.044	14.316	540.000
HDPE	.35% CAPOW L38/H	191-2A(006)	0.255	0.045	2.231	0.970	0.044	8.679	289.037
SP006 AND									
SP007	19% C-PLASTIC	191-3A(007)SANDED	0.230	0.043	2.106	0.480	0.044	4.295	103.953
		191-4A(007)	0.290	0.044	2.595	0.580	0.044	5.190	100.000
192A	06/18/93	LAMINATE 295F/3 TONS							
	80% [redacted]	192-1A	1.300	0.051	10.036	3.500	0.049	28.121	180.220
[redacted] POWDER	.35% CAPOW/L38H	192-2A	1.900	0.049	15.266	4.400	0.050	34.646	126.947
HEATED ON	V-BLENDED 6/1/93								
HOT PLATE									
	19% C-PLASTIC								
193A	06/18/93	LAMINATE 295F/3 TONS							
	85% [redacted]								
[redacted] POWDER	.5% CAPOW/L38H	193-1A(SANDED)	0.190	0.062	1.207	0.820	0.062	5.207	331.579
HEATED ON	V-BLENDED 6/1/93	193-2A	0.260	0.058	1.765	2.200	0.059	14.680	731.812
HOT PLATE									
	19% C-PLASTIC								

REVISED- 15-JUL-1993 STABILITY TESTING

SAMPLE NO.	DATE	MATERIAL COMPOSITION	RESISTANCE (OHM) BEFORE	THICKNESS (INCH) BEFORE	RESISTIVITY (OHM-CM) BEFORE	RESISTANCE (OHM) AFTER	THICKNESS (INCH) AFTER	RESISTIVITY (OHM-CM) AFTER	PERCENT CHANGE (%)
194A	06/24/93	LAMINATE 295F/3 TONS							
	85% [redacted] RIBBON	194-1A(.008")	0.265	0.031	3.366	8.500	0.032	104.577	3007.311
CRISS-CROSS	FROM [redacted]	194-2A(.008")	0.320	0.042	3.000	>100	0.043		
PRESS OF	.008" AND .010"	194-3A(.010")	0.290	0.040	2.854	>100	0.040		
.008" AND	THICK	194-4A(.010")	0.310	0.034	3.590	44.000	0.034	509.495	14093.548
.010" RIBBON									
	19% C-PLASTIC								
195A	06/28/93	LAMINATE 295F/3 TONS							
	85% [redacted] LOADING	195-1A	0.460	0.046	3.937	0.650	0.046	5.563	41.304
85% [redacted]	.5% CAPOW	195-2A	0.580	0.046	4.964	0.720	0.046	6.162	24.138
.5% CAPOW	SANDED BEFORE								
EXTRUDED	LAMINATION								
6-16-93									
	19% C-PLASTIC								
196A	06/28/93	LAMINATE 295F/3 TONS							
	80% [redacted] LOADING								
80% [redacted]	.35% CAPOW	196-1A	1.150	0.044	10.290	1.150	0.045	10.061	-2.222
.35% CAPOW	SANDED BEFORE	196-2A	1.050	0.045	9.186	1.300	0.045	11.374	23.810
EXTRUDED	LAMINATION								
6-16-93									
	19% C-PLASTIC								
197A	06/29/93	LAMINATE 295F/3 TONS							
	85% [redacted] LOADING								
HDPE	.35% CAPOW	197-1A(315F)	0.240	0.044	2.147	0.700	0.045	6.124	185.185
SP006	SANDED BEFORE	197-2A(315F)	0.275	0.045	2.406	0.650	0.045	5.687	136.364
VARY TEMP	LAMINATION	197-3A(335F)	0.225	0.045	1.969	0.730	0.045	6.387	224.444
		197-4A(335F)	0.360	0.051	2.779	0.810	0.051	6.253	125.000
HAND-	19% C-PLASTIC	197-5A(355F)	0.240	0.044	2.147	0.370	0.045	3.237	50.741
COMPOUNDED		197-6A(355F)	0.220	0.045	1.925	0.275	0.045	2.406	25.000
		197-7A(375F)	0.235	0.045	2.056	0.290	0.045	2.537	23.404
		197-8A(375F)	0.215	0.045	1.881	0.300	0.045	2.625	39.535
		197-9A(400F)	0.205	0.045	1.794	0.275	0.045	2.406	34.146
		197-10A(400F)	0.200	0.046	1.712	0.275	0.045	2.406	40.556
198A	06/29/93	LAMINATE 295F/3TONS							
HDPE	85% [redacted] LOADING	198-1A(315F)	0.430	0.049	3.455	0.860	0.049	6.910	100.000
SP007	.35% CAPOW	198-2A(315F)	0.410	0.050	3.228	1.250	0.050	9.843	204.878
VARY TEMP	SANDED BEFORE	198-3A(335F)	0.295	0.047	2.471	0.820	0.047	6.869	177.966
	LAMINATION	198-4A(335F)	0.320	0.052	2.423	0.540	0.052	4.088	68.750
HAND-		198-5A(355F)	0.280	0.046	2.396				
COMPOUNDED	19% C-PLASTIC	198-6A(355F)	0.230	0.046	1.969				
		198-7A(375F)	0.210	0.047	1.759				
		198-8A(375F)	0.360	0.049	2.892				
		198-9A(400F)	0.245	0.048	2.010				
		198-10A(400F)	0.240	0.045	2.100				

STABILITY TESTING WAS SHORTENED BY ONE DAY ON SAMPLES 1-4

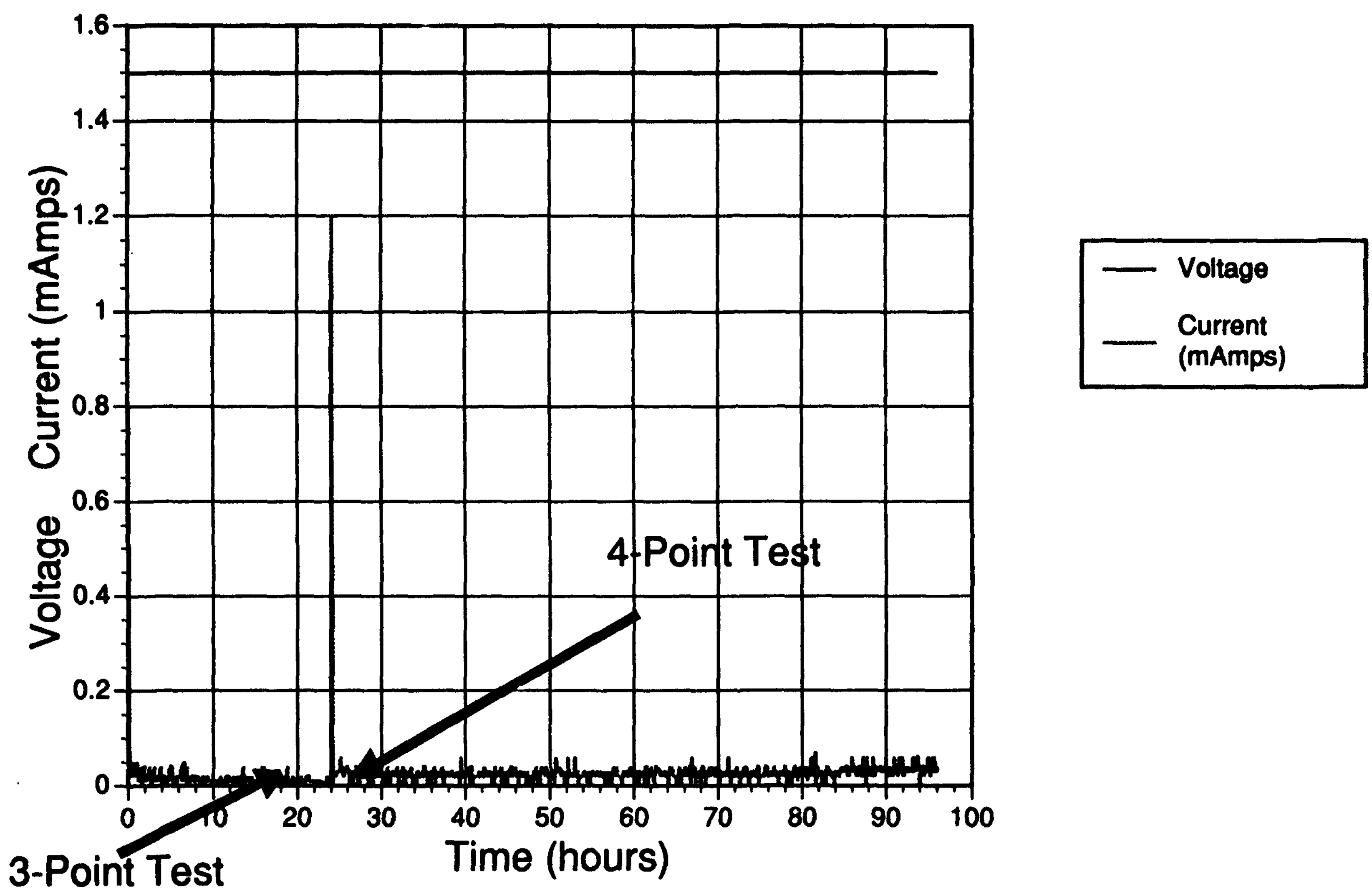

Figure 7
Sample 96a-1
0.050" Microthene 80% Loading
3.2% Resistivity Increase

Stability testing a bipolar substrate and/or conductive filler has been developed at JCBGI over many years. The method used for this contract is the 3 and 4 point tests were the bipolar substrate is exposed to a constant potential of 1.5 volts. The substrate is sandwiched between the two cells and serves as the working electrode. A constant potential of 1.5 volts is applied to the substrate. In the three electrode system were the current is collected at the top of the substrate. After 24 hours the test is switched to a four point test with the current being collected after it passes through the substrate. With the potential remaining at 1.5 volts, the test continues for a minimum of 3 additional days. Ideally, if the substrate was not porous, the current would remain the same for both the 3 and 4 point tests. A rising current during testing would suggest a porous substrate or a non-stable conductive filler.

The second test the substrate must pass is the conductivity test. The conductivity of the part is measured before and after the stability test. If the conductivity increases more than 20%, the accuracy of the conductivity test $\pm$ 10-20%, the part has exhibited either porosity or the conductive filler is not stable. Since, Conduflow has been successfully tested, an increase in resistivity would indicate a porosity problem. The increase in resistance can be explained by the fact that the C-black side would be exposed to the positive potential by the porosity in the Conduflow part, which causes the C-black to oxidize and become non-conductive. In parts were the conductive filler is not stable the increase in resistivity is explained by the non-stability of the filler.

JCBGI's stability testing station consists of one four channel power supply which is controlled using a Macintosh computer and Labview software. The software was written by JCBGI and in conjunction with the computer makes the power supply act like a 4 channel potentiostats. The computer also the data collection device, recording voltage and current acceptance every 30 seconds.

6. BATTERY TEST RESULTS:

Four different four volt batteries have been tested. A summary of the test results and battery information can be found in Figure 8. The batteries are made using lead sheet terminal electrodes and one bipolar substrate. On the bipolar substrate 1g of Pb powder was sintered on to help promote paste adhesion. A number of pasting trials have been conducted and it was found that the PAM would not adhere to the bipolar substrate without some form of Pb adhered to the surface. Parts pasted without any Pb displayed no paste adhesion, the PAM would shear off at the substrate to PAM interface in sheet form.

Battery ID	% Filler	% CA	Thick	Ω-cm	PAM Weight	NAM Weight	Active Area
159	82.5	0.35	0.086"	1.83	34g	34g	12"
160	80.0	0.35	0.087"	3.14	34g	34g	12"

Battery terminals are lead sheets with 12g of active material on each. Separator thickness is 0.030", with the battery being assembled using gasket material and a glue to prohibit leaking. Less than 1g of lead dust was sintered on each bipolar plate to aid in paste adhesion. Acid was introduced via a vacuum fill technique. Formation took place over 48 hours with a total of 79 ah/# PAM (Positive Active Material). Battery 160 developed a short thorough the separator during formation. The separator was replaced and the formation was completed. Discharge data from both batteries follow.

Battery #159

Cycle	Date	IR	Dis I	D Time	% Recharge	Comments
1	3/25	40	10	41s	1120	
2	3/26	40	10	85s	1116	
3	3/29	43	20	31s	643	
4	3/30	51	10	22s	256	Cold Crank
5	3/31	45	10	35s	243	
6	4/1	57	10	21s	1134	
7	4/2	61	10	53s	1103	
8	4/5	76	10	15s	2971	
9	4/6	76	10	65s	596	
10	4/7	88	10	69s	494	
11	4/8	95	10	70s	140	
12	4/9	105	10	24s	1100	
13	4/12	105	10	76s	140	
14	4/13	115	10	70s	140	
15	4/14	110	5	286s	140	
16	4/15	120	5	284s	140	
17	4/16	130	10	89s	140	
18	4/19	130	10	40s	140	
19	4/20	150	10	43s	200	
20	4/21	145	10	60s	200	
21	4/22	150	10	65s	200	
22	4/26	170	10	19s	200	
23	4/27	170	10	89s	200	
24	4/28	170	10	89s	200	
25	4/29	175	10	91s	200	
26	4/30	180	10	99s	300	

Figure 8: Battery Test Data

Battery #160

Cycle	Date	IR	Dis Current	Dis Time	% Recharge	Comments
1	3/26	40	10	150s	553	
2	3/29	49	20	69s	221	
3	3/30	56	10	109s	122	Cold Crank
4	3/31	56	10	123s	127	
5	4/1	80	20	14s	530	
6	4/2	84	10	125s	193	
7	4/5	105	10	108s	167	
8	4/6	115	10	127s	133	
9	4/7	140	10	148s	133	
10	4/8	160	10	158s	140	
11	4/9	170	10	148s	200	
12	4/12	205	10	120s	140	
13	4/13	220	10	135s	140	
14	4/14	220	10	150s	125	
15	4/15	255	10	241s		

Teardown Performed on 4/16/93

Battery #159-B

Cycle	Date	IR	Dis Current	Dis Time	% Recharge	Comments
1	4/8	42	10	214s	271	
2	4/9	42/84	24	2s	388	Cold Crank
3	4/12	42	20	56s	140	
4	4/13	49	24	24s	140	
5	4/14	49	10	67s	200	
6	4/15	55	5	224s	200	
7	4/16	56	10	113s	140	
8	4/19	65	10	57s	140	
9	4/20	72	10	39s	200	
10	4/21	67	10	39s	200	
11	4/22	80	10	38s	200	
12	4/26	96	10	9s		
13	4/27	72	10	132s	200	
14	4/28	74	10	97s	200	
15	4/29	76	10	83s	200	

Teardown Performed on 4/30/93

Figure 8 Cont.

Battery teardowns have determined that failure has been caused by lack of active material adhesion. The PAM would not be adhered to the substrate. This causes excessive resistance between the active material/substrate interface and severely hinders battery performance.

7. NEXT STEPS:

The three areas to be addressed in the remaining months of the contract are- Produce thinner more conductive substrates; Decide on a method to produce cell to cell sealing; Improve positive active material adhesion to the substrate. Of the three issues, the most critical is the adhesion issue. The first issue should, without any material improvements or breakthroughs, evolve simply from process optimization. The sealing issue is not seen as a major problem because of the material used as a base resin, PE, can be easily thermally bonded too. JCBGI has extensive experience in using vibration welding and infrared welding techniques to provide cell to cell sealing for bipolar batteries. These techniques can be easily modified for use in this project. The main development issue will be PAM adhesion to the substrate. Initial battery testing has shown that this has been the performance limiting area on all of the batteries made. Future development efforts will be concentrated on this area.